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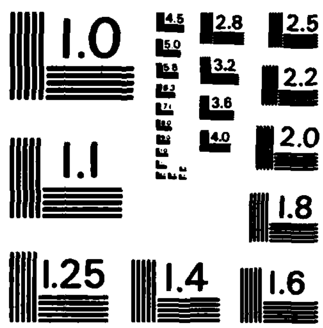

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TECHNICAL REPORT 158

TRAINING CAPABILITIES TEST OF ELECTRONICS EQUIPMENT MAINTENANCE TRAINER (EEMT): FINDINGS AND CONCLUSIONS

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TRAINING ANALYSIS AND EVALUATION GROUP
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Technical Report 158

TRAINING CAPABILITIES TEST OF ELECTRONICS EQUIPMENT MAINTENANCE TRAINER (EEMT): FINDINGS AND CONCLUSIONS

Louis F. Cicchinelli
Robert A. Keller
Kenneth R. Harmon

Denver Research Institute
University of Denver

Prepared for

Naval Training Equipment Center
Training Analysis and Evaluation Group (Code 1)

July 1984

T. W. McNaney

T. W. McNANEY, Director
Training Analysis and Evaluation Group

W. H. Lindahl

W. H. LINDAHL, Technical Director
Naval Training Equipment Center

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The objective of the study was to design and conduct a Training Capabilities Test (TCT) of the Electronic Equipment Maintenance Trainer (EEMT) within the Primary Power portion of the AN/SPS-10 radar training course at ET "A" School, Naval Training Center, Great Lakes. The TCT consisted of a series of studies which examined the training effectiveness, operational suitability, and life cycle cost of the EEMT as it supports the training system.

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We are especially grateful to Mr. Curtis Cordell, the project monitor, and Mr. Roger Nutter, the technical monitor, for their support and assistance throughout the project.

SUMMARY

Objective

The objective of this study was to design and conduct a Training Capabilities Test (TCT) of the 2D subsystem of the Electronic Equipment Maintenance Trainer (EEMT) within the Primary Power portion of the AN/SPS-10 radar training course at ET "A" School, Great Lakes Naval Training Center, Illinois. The TCT was designed to determine the training effectiveness, operational suitability, and cost of the 2D EEMT as it supports the training system in a specific training environment.

Background

Operational readiness of Naval electronic equipment depends, in large part, on the ability of enlisted technicians to perform appropriate maintenance actions. Effective technician training, which must be accomplished at reasonable cost, is then a necessary condition for military preparedness. Based on the assumption that maximum transfer of training will occur if technicians are trained on the same equipment that they are subsequently required to maintain, the Navy has traditionally used operational equipment to assist instructors in a variety of training tasks. The use of operational equipment, however, can be costly, dangerous, inflexible, unsupported by training materials, and in some instances the fleet may be deprived of their full allotment of operational hardware. With the rapid changes in technology and the increased complexity and cost of electronic devices, more often than not, schools are forced to train students on outdated equipment which is itself difficult to maintain, particularly with the limited availability of parts and the low priority assigned to training needs in the supply system. The 2D EEMT was designed and developed to overcome many of the problems associated with using operational equipment for training electronics technicians.

Approach

The TCT was composed of a series of studies designed to evaluate the training effectiveness, operational suitability and cost effectiveness of the 2D EEMT system for training Navy electronics technicians. Three training modes were selected for study: an operational equipment only mode, a low EEMT mode in which the 2D EEMT was used for approximately 30 percent of training, and a high 2D EEMT mode in which the 2D EEMT was used for approximately 60 percent of training. In addition, two training formats, individual and pair, were employed. The total amount (in hours) of laboratory training was the same in all conditions.

Existing measures and tracking procedures were incorporated to the greatest extent possible. Scores from the ET "A" School Performance Test (PT) were the principal measure of 2D EEMT training effectiveness. Student and instructor attitudinal data pertaining to the use of the 2D EEMT and operational

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equipment in training were obtained. Limited follow-up data were collected to track the need for retraining subsequent to "A" School. Operational suitability data were collected tc determine 2D EEMT reliability, maintainability, availability for training, appropriateness for Primary Power training, and adaptability to other training areas. The respective costs of the 2D EEMT and operational equipment over a 15-year life cycle were compared. The comparative costs of the 2D EEMT and operation equipment in selected training scenarios were also examined.

Results

The accuracy of troubleshooting performance was essentially equal when students were trained on either the 2D EEMT or operational equipment. Students trained on operational equipment appeared more efficient than those who received 2D EEMT training, and students trained as individuals were slightly more efficient than those trained in pairs. The 18 2D EEMTs were available for about 72 percent of the time for both laboratory and extra study/remediation use. The life cycle cost comparison favored the 2D EEMT over the operational equipment if at least three units are acquired. Considering investment costs only, a 50 percent savings was estimated for the purchase of 20 2D EEMT units as opposed to 20 AN/SPS-10 units. Instructors and students were in agreement that the 2D EEMT had an important and useful, but limited, role as a supplement to operational equipment training.

Conclusions and Recommendations

When used in conjunction with operational equipment, the 2D EEMT can reduce reliance on operational equipment trainers without a reduction in training effectiveness. The 2D EEMT is equally effective for low, middle, and high ability students and is an effective alternative to operational equipment for extra study and remediation. It provides increased opportunity for troubleshooting practice due to reduced safety and instructor monitoring requirements.

The 2D EEMT is easily transportable, compatible with the ET "A" School environment, and adaptable to other training environments. Maintainability and reliability of the 2D EEMT, however, would be enhanced by provision of a comprehensive spare parts package and modifications to the touch panels used for student input.

The life cycle cost savings realized by using 2D EEMTs instead of operational equipment is largely dependent on the initial investment costs associated with the actual system in question.

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I. INTRODUCTION

This report presents the results of the Training Capabilities Test (TCT) of the Electronic Equipment Maintenance Trainer (EEMT). This test and evaluation was conducted during Phase II of contract no. N61339-81-C-0126 in accordance with the approved TCT plan (Cicchinelli, Keller, & Harmon, 1982) developed during Phase I of this contract. The plan was designed to respond to the evaluation requirements of the Naval Decision Coordinating Paper (NDCP) (Department of the Navy, 1978) and the Device Test and Evaluation Master Plan (DTEMP) (Pine, Daniels, & Malec, 1981) for the EEMT and subsequently modified to correspond with the use made of the EEMT by the Electronic Technician (ET) "A" School, Service School Command, Great Lakes, Illinois.

Problem

Operational readiness of Naval electronic equipment depends, in large part, on the ability of enlisted technicians to perform appropriate maintenance actions. Effective technician training, which must be accomplished at reasonable cost, is then a necessary condition for military preparedness. Based on the assumption that maximum transfer of training will occur if technicians are trained on the same equipment that they are subsequently required to maintain, the Navy has traditionally used operational equipment to assist instructors in a variety of training tasks. In recent years, experience has dictated that the use of operational equipment in training environments is not always the optimal approach to instruction.

The use of operational equipment used in a training capacity can be costly, dangerous, inflexible, unsupported by training materials, and in some instances the fleet may be deprived of their full allotment of operational hardware. With the rapid changes in technology and the increased complexity and cost of electronic devices, more often than not, schools are forced to train students on outdated equipment which is itself difficult to maintain, particularly with the limited availability of parts and the low priority assigned to training needs in the supply system.

The EEMT was designed and developed as a generic trainer intended to overcome many of the problems associated with using operational equipment for training electronics technicians.

Purpose

The purpose of this investigation was to design and conduct a TCT of the EEMT. Testing of training devices in an operational environment is more limited in scope than the Operational Test and Evaluation required for operational hardware. The TCT was designed to determine the training effectiveness, operational suitability and cost of the EEMT as it supports the training system in a specific training environment.

Background

Impetus for the EEMT

Practice of operation and maintenance tasks is a critical element of "A" School electronics training in the Navy. Troubleshooting and hands-on training have been accomplished primarily through the use of operational equipment. The Operational Requirement, PN-50 (1976), outlined a number of problems with this approach and established general goals and criteria for the training system. In response, the Navy initiated an engineering development effort to develop a general purpose EEMT system that could reduce reliance on operational equipment at the "A" School level.

The EEMT project was divided into four phases: (1) concept formulation, (2) system definition, (3) prototype development, and (4) system test and evaluation. A basic system design was drafted as part of the first phase of the project. At the same time, the ET School at Great Lakes, Illinois and the Electronics Warfare Technician (EW) School at the Naval Technical Training Center, Pensacola, Florida were designated as the target users of the EEMT (Wylie & Bailey, 1978). Phase II resulted in the prototype design selection (Pine, Koch, & Malec, 1981). Specifications were prepared for a two-dimensional (2D) subsystem with interactive displays and a three-dimensional (3D) subsystem with simulated generic electronic equipment. The prototype development phase (Phase III) resulted in two subsystem configurations. The final project phase, system test and evaluation, is the focus of this report.

The EEMT system, and the 2D subsystem in particular, is the prototype version of the Generalized Maintenance Training Simulator (GMTS) also developed by the Navy Personnel Research and Development Center (Towne & Munro, 1981). The purpose of the GMTS was to demonstrate the feasibility of the basic system concepts and technology and to facilitate the development of prototype specifications. While the hardware has changed substantially during this evolution from GMTS to EEMT, the functional characteristics of the two training systems remain essentially the same.

To date, the GMTS has undergone three field evaluations in different ET training settings (Rigney, Towne, King, & Moran, 1978; Rigney, Towne, Moran, & Mishler, 1978; Towne, Munro, & Johnson, 1983). Based on the favorable results of these studies, the training effectiveness of a 2D trainer has already been demonstrated, at least in principle, and thus, the major focus of this TCT should be on the integrated 2D-3D system and the 3D EEMT subsystem. However, the primary focus of two of these field tests was to demonstrate the feasibility and applicability of the GMTS concept. Neither study was designed to evaluate the training effectiveness, cost, or suitability of the system as an integral part of instruction. Only Towne, Munro, and Johnson (1983) examined the training effectiveness of the GMTS in a training laboratory setting. Thus, the TCT of the EEMT system was originally designed to give equal emphasis to the training effectiveness, operational suitability and cost of both the 2D and 3D subsystems, an approach directed by the DTEMP (Pine, Daniels, & Malec, 1981).

Modifications to the TCT Scope

At the direction of the Navy, on January 25, 1982, the EW School was officially dropped as a site for the TCT. On February 16, 1983, a second major change in the TCT was made. Since the 3D EEMT subsystem delivered to the ET School could not be integrated into the existing curriculum without modifications to the 3D lessonware delivered and substantial additional lessonware development to support a 2-week instructional program, the evaluation of this unit was deleted from the TCT plan (Cicchinelli, Keller, & Harmon, 1982).

System Description

The functional description of the 2D EEMT was based on the premise that the training system would be generic. It was hypothesized that more students could be trained in less time, more cost effectively, and to a greater proficiency level utilizing the EEMT system as an enhancement to current operational equipment. The 2D EEMT was not considered as a replacement system because technical training requires technical equipment.

The 2D EEMT system was intended to provide trainees with practice on generic preventive and corrective maintenance procedures. The system provided self-paced instruction adaptable to the skills and needs of individual trainees. Immediate feedback was provided on trainee performance and the system provided computer-assisted and limited computer-managed instruction such that student performance skills were tested and recorded.

The 2D hardware consists of a microcomputer, image and adaptive displays fitted with touch-sensitive panels for user input, and a videodisc player. A portable terminal/printer, which can be shared among 2D EEMT consoles, provides for instructor input to the system, lessonware authoring, and access to student performance data. Figure 1 shows the 2D hardware configuration, including the instructor terminal and student console used for training. The adaptive display presents text, problems, and menu choices; the image display presents equipment images from a photographic data base. This data base is arranged hierarchically and includes an overall system image together with successively more detailed images of system components and subcomponents.

The 2D unit is primarily a stand-alone, equipment-specific trainer which uses both structured and free-play lessonware. Structured lessons provide instruction on various topics in a typical interactive tutorial format. Free-play lessons present troubleshooting problems and students are allowed to observe and manipulate the simulated equipment until a solution is reached. Free-play lessons closely parallel laboratory training problems.

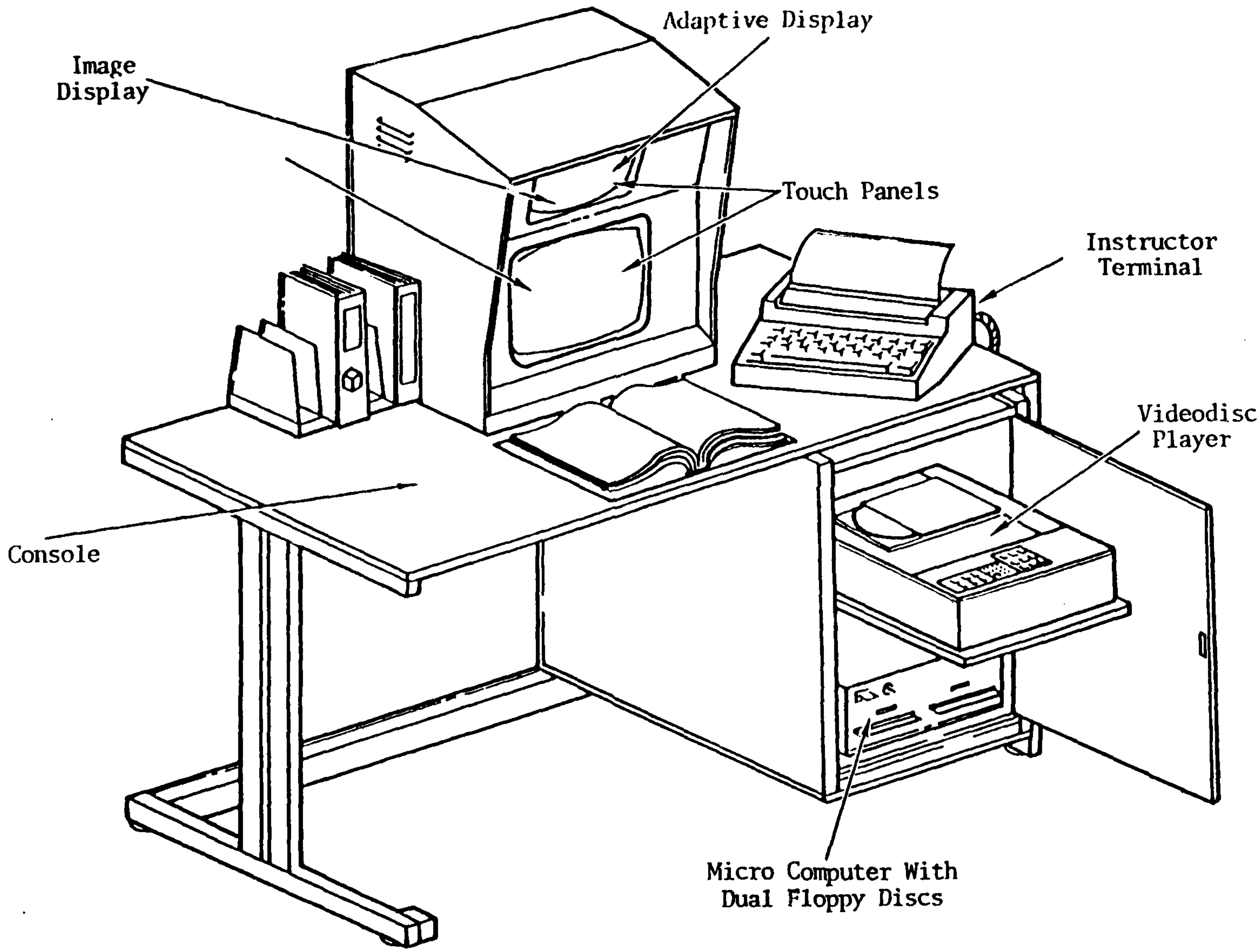

Figure 1. Illustration of 2D EEMT student station with the instructor terminal.

II. APPROACH

The test and evaluation of the 2D EEMT was conducted in accordance with the statement of work (Revision B, 2-16-83) and the approved TCT plan developed during Phase I of this contract. The plan specifically addressed three aspects of the training device: training effectiveness, operational suitability, and cost. To expedite the collection of relevant data, the plan was developed to integrate with the existing training environments and the intended uses of the 2D EEMT in the training system.

The Training Environment

The test and evaluation of the 2D EEMT was conducted primarily on-site in the ET "A" School at Great Lakes Naval Training Center.

All prospective ET students receive training in Basic Electronics and Electricity (BE&E) prior to reporting to the ET School as depicted in Figure 2. ET students are then given Advanced Electronics training followed by Communications instruction, or the Fundamentals of Tubes and Transistors for ET students in the nuclear field. The length of training, therefore, depends on whether a student is designated ET or a nuclear ET. Nuclear trained students comprise about one-third of each ET class of about 66 students, and an effort is made to consolidate them into a single training shift. Approximately 22 students are assigned to each of three shifts beginning each week. As Figure 2 shows, all ET students are then merged again for 6 weeks of AN/SPS-10 Radar training. The primary application of the EEMT system was in this final course. Specifically, eight 2D EEMT units were placed in the Primary Power laboratory section (the first 2 weeks) of the AN/SPS-10 Radar Systems instruction. This laboratory had 10 work stations using operational AN/SPS-10 equipment. Radar training at ET "A" School is equipment specific and uses the surface search AN/SPS-10 equipment for all hands-on training and testing. Additional 2D EEMT units were placed in the extra study/remediation room associated with Radar Systems.

Existing student assessment methods and record keeping procedures were identified as part of the course review. Performance Tests (PTs), Unit Tests, maintenance forms, and other data collection instruments were also identified. PTs for the radar segment of instruction are indicated in Figure 2.

During the planning phase, ET School personnel made two points very clear: (1) the EEMT would play only a supplemental role in instruction and (2) the final decision regarding acceptance of the units (hardware and lessonware) would be dependent on the findings of an on-site shakedown period. The use of the AN/SPS-10 as a representative radar trainer fills a greater need than simply generic training, because nearly every ship has an AN/SPS-10, and there is no "C" School for this radar system. For this reason, ET personnel stated that it could not be effectively replaced as a training tool by the generic EEMT system. Furthermore, instructors reported that students are "too sophisticated" for generic trainers by the time they reach ET School. Specific issues identified during preliminary on-site interviews included:

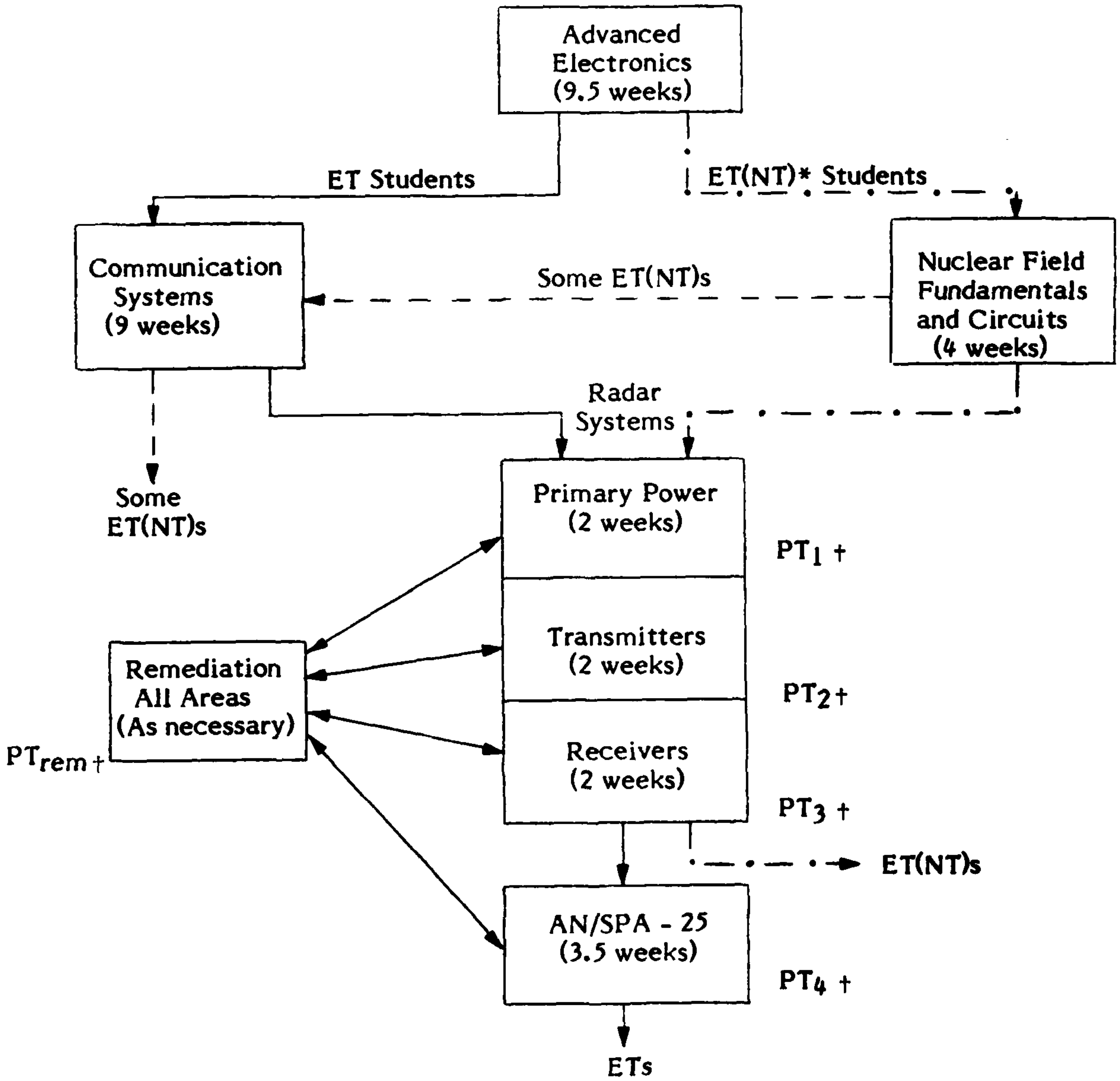

Figure 2. Illustration of the student flow in the ET School.

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*ET(NT)--electronics technicians trained in the nuclear field specialty area.

†PT is the performance test for a given training segment.

- The main use of the 2D EEMT subsystem was to be during the first 2-week area of Radar Systems (Primary Power). The first week focused on general radar issues, while the second week focused on the AN/SPS-10 power supply.

- The 2D units were to be dispersed among existing laboratories and remedial work areas. In the laboratories, only free-play problems were to be used. Students were to be rotated between the 2D EEMTs and the operational equipment stations.

- Additional lessonware was to be developed by the Instructional Program Development (IPD) Center for the receiver/transmitter portions of AN/SPS-10 training and for the Communications Systems block of instruction that precedes radar.

- The EEMT was to be considered particularly well suited for extra study/remedial training because of its accessibility and the fact that virtually no instructor monitoring was required. Structured lessons were considered to be suitable only for remedial instruction.

The Training Capabilities Test Plan

The test and evaluation plan, developed during Phase I of this contract, outlined a series of studies designed to evaluate the training effectiveness, operational suitability, and cost effectiveness of the EEMT system for training Navy electronics technicians. This modular approach was selected for the following reasons:

- The potential impacts of unscheduled changes in the training/testing curriculum subsequent to TCT start-up would be minimized because they could be restricted to a particular evaluation element. Thus, the entire test and evaluation would not be compromised by deviations from current training practices.

- This approach provided the flexibility necessary to be responsive to changing environmental constraints. Variability in factors such as instructor availability, student flow, and equipment reliability would have little impact on evaluation outcomes.

- The focus of each evaluation element could be directed toward a particular instructional area without affecting other components of the plan. In this way, each element was focused on the most relevant training circumstances available.

- This approach allowed better coordination between evaluation efforts and the projected EEMT implementation schedule; data collection could proceed for one study while the planning and implementation for a second study was still in progress.

The TCT placed only minimal demands on the ET School environment. Existing measures and tracking procedures were incorporated to the greatest extent possible. School personnel had only a few additional data collection responsibilities as a consequence of the evaluation effort. Thus, administrative and technical assistance were the primary types of support required from ET School personnel.

Another feature of this evaluation was its use of historical student records as a source of data for some of the study groups. Student records are maintained at ET School for a period of 2 years following student graduation. By capitalizing on the availability of such information, the allocated 100 experimental students were reserved for the study of key training issues; there were no restrictions on the numbers of conventionally trained students available for comparison. Confidentiality was maintained with respect to all student records.

Data Collection

The data collection effort necessary to support the TCT was concerned primarily with the aggregation and refinement of existing measures rather than the development of new performance measures. Student aptitude, prior achievement, and performance measures are routinely collected by ET School personnel. Data related to equipment reliability and maintainability were also tracked by school personnel. Data collection forms introduced by DRI, as well as those already in use by the ET School, are discussed below.

A second aspect of the data collection effort included a review of the EEMT laboratory training and remediation experiences of TCT subjects. Since this information was stored by the EEMT system on individual student diskettes, an appropriate and compatible I/O capability was required to collect this information. The two existing instructor terminals were already extensively used to manage student training and to perform preventive maintenance functions. An additional terminal was acquired for the collection of evaluation data to minimize the impact of the TCT data collection process on the training environment.

Training Effectiveness

The effectiveness of the EEMT system for training ET students was assessed primarily through the examination of student performance measures. Student scores from all "A" School instructional areas were transferred from student records to individual ET Student Data forms.

Previous Navy guidelines, including the contract statement of work, had suggested the use of pre- and postinstruction measures of student performance for evaluating training effectiveness. However, this approach was not particularly well suited to the ET School environment. First, the use of pre- and posttest measures precluded the use of historical student data. Second, the focus of training was on hands-on proficiency. For safety reasons, a hands-on test could not be administered prior to adequate familiarization and training with operational AN/SPS-10 equipment. In lieu of pretesting, the TCT included the use of previous aptitude and achievement measures to ensure that different training groups were equated in terms of prior abilities.

Scores from ET School PTs were the principal measure of EEMT training effectiveness. This approach to performance measurement was chosen because (1) the nature of the eventual EEMT intervention was uncertain at the outset, (2) PTs were administered in a systematic and relatively consistent manner for all equipment specific training areas, (3) PTs were administered in a hands-on troubleshooting format, and (4) extensive historical performance data were available concerning each possible PT problem.

Limited follow-up data were also collected in order to track the need for retraining subsequent to "A" School. An EEMT Follow-up Survey form was used for this purpose (rf. Section A-1 of Appendix A).

System Operational Suitability

Certain operational suitability information was routinely collected on-site at the ET School using student EEMT Trainer Critiques, EEMT Run-time Logs, and standard ET School maintenance forms (2-KILO, Daily Production Reports and Down Equipment Logs). The EEMT Trainer Critique form used at the school was too general to meet the needs of the TCT. A more detailed DRI-generated form (rf. Section A-2 of Appendix A) was used to collect specific student feedback about the operational equipment and EEMT trainers. In addition, two new data collection forms were used. The first, an EEMT Training Availability form, was designed to track the availability of EEMT equipment for training (rf. Section A-3 of Appendix A). The second form, the Instructor Critique, was used to determine the extent to which instructors were willing to use and accept the EEMT system as an integral part of the ET training program (rf. Section A-4 of Appendix A).

Much of the data on system capabilities was obtained during on-site interviews with ET School personnel. Since this information was collected on an ongoing but intermittent basis, a structured interview guide was used (rf. Section A-5 of Appendix A).

System Costs

System cost data were collected on-site at both the Navy Personnel Research and Development Center and the Great Lakes Naval Training Center. Cost Worksheets were used to code costs related to the development and use of

the EEMT system. These forms were derived from the cost model outlined in the TCT plan and were designed to record expenditures, personnel time, and facility requirements for hardware, software, lessonware, and support. Enlisted personnel costs were derived from the Life Cycle Navy Enlisted Billet Costs--FY 81 (Koehler & Turney, 1981).

Evaluation Questions

The series of studies were designed to address a wide range of TCT issues. The evaluation questions listed below were derived primarily from the NDCP and the DTEMP. The questions have been grouped to correspond to the three major components of the TCT: training effectiveness, operational suitability, and cost considerations. In some cases, these evaluation questions were translated to more testable hypotheses which relate to specific TCT studies. These hypotheses are presented in the appropriate sections thoughout this report.

With respect to training effectiveness, the evaluation questions examined were:

- Will the EEMT system improve the transition between the electronics fundamentals and equipment-specific segments of ET electronics maintenance training?
- Can a training improvement of at least 10 percent be demonstrated through use of the EEMT system?
- Can the EEMT system maximize the effectiveness of individual hands-on maintenance training?
- Can the EEMT system accommodate low, middle, and high ability students?
- Will the use of EEMT training result in a greater need for refresher training at "C" School than conventional training?
- Do the skills and knowledge learned on the EEMT system generalize to the larger population of equipment maintained by ETs?
- Can the EEMT system reduce reliance on operational prime equipment in ET training?

The evaluation questions examined related to operational suitability were:

- Are the planned spares maintained on hand sufficient to repair all critical/major failures?

- Can the EEMT be shown to be available for scheduled operation a minimum of nine-tenths (0.9) of the time?

- Does the EEMT incorporate basic system safety principles?

- Does the EEMT incorporate person/equipment interface features that maximize efficient and safe operation and maintenance?

- Is the EEMT system easily transported; can it be easily assembled and disassembled?

- Are the EEMT systems physically, functionally, and electrically compatible with the school laboratory environment?

- Is performance data from the EEMT system interoperable with the Navy CMI system used in the BE&E School?

- Can operators of the EEMT system be trained with no more than 2 weeks of formal training plus on-the-job training (OJT); maintenance personnel trained in no more than 4 weeks of formal training plus OJT?

- Can the EEMT system be maintained and logistically supported by Navy personnel at ET School?

- Are students willing to accept the EEMT system as a viable means of providing ET School training?

- Are instructors willing to accept the EEMT system as a viable means of providing ET School training?

- Is the EEMT system capable of providing hands-on training of electronic maintenance tasks and principles?

- Can the EEMT system be used to train in vacuum tube, solid state, and/or large-scale integrated (LSI) technologies?

- Can the EEMT system be used to provide generic systems training, that is, training on tasks and equipment common to the population of tasks and equipment used by ETs?

- Can the EEMT system adapt to changing job demands?

- Does the use of the EEMT system allow for an increase in the student/instructor ratio?

With respect to cost, the evaluation questions examined were:

- Can the EEMT system provide electronics training at less than the cost needed to acquire, operate, and maintain conventional hardware to accomplish equivalent training?

- What specific recurring design-to-cost goal per student station can be met (including lessonware and course materials)?

In the following sections of this report, these evaluation questions are discussed in conjunction with the specific evaluation methodologies used and the findings obtained in the three major components of the TCT.

III. TRAINING EFFECTIVENESS

This section describes three TCT studies that examined the training effectiveness of the 2D EEMT. The first relied on an analysis of existing ET School student records to study possible EEMT training effects during the Primary Power area of AN/SPS-10 radar instruction. The second used traditional experimental methods to also study the effects of EEMT training during Primary Power. The third study was designed to examine the long-range impacts of EEMT training.

Study 1: Analysis of Historical Data

Experimental method relies on comparisons among treatment conditions in which subjects are treated identically except for the factor or factors under investigation. Traditionally, these conditions are realized through the use of controlled settings and random assignment of subjects. However, through judicious selection of available data, it is often possible to approximate an experimental situation. Study 1 was designed in this way to provide an initial assessment of the training effectiveness of the 2D EEMT equipment through a review of historical ET School student files.

Specifically, the following hypotheses were addressed:

- The 2D EEMT system improves the performance of ET trainees when employed for laboratory and/or remedial instruction of electronics maintenance.
- The 2D EEMT system improves performance of ET trainees when used to deliver necessary laboratory-related remedial instruction only.
- Use of the 2D EEMT system results in a 10 percent increase in student performance as compared with conventional training.
- The 2D EEMT system improves the performance of low, middle, and high ability students.
- The 2D EEMT system reduces reliance on operational prime equipment in ET training.

Method

All data for Study 1 were collected from historical student records that were maintained on-site at the ET School. To ensure comparability of previous training experiences, only records of non-nuclear ET students (603 V designation) were reviewed.

Student records were assigned to one of three independent treatment conditions as defined by the time periods of Primary Power training shown in Table 1. These three time periods correspond to different levels of operational and 2D EEMT equipment availability for laboratory and extra study/remedial training. That is, students whose records were assigned to Condition 1 received training on operational equipment only. During the time period for Condition 2, operational equipment only was available for laboratory training, but the 2D EEMT equipment was available for extra study/remediation. During the time period for Condition 3, both operational and 2D EEMT equipment were used for laboratory training; the 2D EEMT was also available for extra study/remediation. In general, students were trained on operational AN/SPS-10 equipment in pairs or groups of three; EEMT training was typically conducted individually, although students were occasionally trained in pairs on the 2D EEMT.

It is important to recognize the difference between the assignment of student records to experimental conditions in terms of equipment availability, as in this study, and assignment on the basis of the actual types of training received by each student (as in Study 2). Detailed information concerning the nature of each student's Primary Power training experiences was not available from historical records. It is known that laboratory training for Conditions 1 and 2 consisted entirely of operational equipment training and that for Condition 3, operational equipment training was supplemented by limited 2D EEMT use. Typically, use of the 2D EEMT consisted of a brief "light off" lesson which reviews system turn-on procedures, a "normal operation" lesson during which students are able to spend an unspecified amount of time examining normal system operating conditions, and one or two troubleshooting lessons. While extra study/remediation was a significant component of training for most students, it is not known to what extent students in Conditions 2 and 3 made use of the 2D EEMTs.

Matched samples of student records were created on the basis of student sex and ET School achievement prior to radar training. The resulting sample sizes, 72 per Condition, are also shown in Table 1. These samples were then divided into three equal subsamples on the basis of prior achievement to indicate students of low, middle, and high ability. Mean cumulative ET School grade averages prior to radar were 80.22, 83.96, and 88.65, respectively for the three ability levels. Thus, 24 student records were assigned to each cell of the resulting three levels of equipment availability by three levels of ability design.

Results

The primary measure of student performance was the PT administered individually to all students at the end of Primary Power training. This test is a hands-on, timed, single fault troubleshooting test conducted using the operational AN/SPS-10 equipment. Any one of 20 different problems (faults) can be selected for a particular PT although the same problem is generally administered to all students on the same training shift. While these problems do vary in difficulty, an

Table 1

Treatment Conditions for Study 1

Condition No.	Intervention Description	Training Period (Primary Power)	Sample Size	Matched* Sample Size
1 (control)	Operational equipment only available for laboratory instruction and extra study/remediation	September 1, 1980 - October 31, 1981	379	72
2 (experimental)	Operational equipment only available for laboratory instruction; 2D EEMTs available for extra study/remediation	January 1, 1982 - April 30, 1982	82	72
3 (experimental)	Both operational equipment and 2D EEMTs available for laboratory instruction; 2D EEMTs available for extra study/remediation	June 1, 1982 - October 31, 1982	139	72

*Matching variables were (1) sex and (2) cumulative ET School grade average prior to AN/SPS-10 radar training.

analysis of PT records showed that the average difficulty of each test administered was relatively stable across the three historical time periods of interest.[1]

Figure 3 shows the PT results as a function of student ability levels and training equipment availability. Overall, mean PT scores were 78.89, 87.88, and 89.98 for Conditions 1, 2, and 3, respectively. Mean scores ranged from 79.88 for low ability students, to 86.12 for middle ability students, and to 91.75 for students of high ability. A complete summary of PT scores is provided in Table B-1 of Appendix B. A 3x3 analysis of variance (ANOVA) revealed significant main effects of both student ability [$F(2,207) = 10.05$, $p < .001$] and training equipment availability [$F(2,207) = 8.07$, $p < .001$] ; the interaction between these variables was not significant. Collapsing over ability levels, further analysis showed that students trained during time periods when the 2D EEMT was available (Conditions 2 and 3 combined) performed better than those who had only conventional AN/SPS-10 training [$t(110) = 3.81$, $p < .001$]. In terms of mean PT scores, this difference represents an 11.3 percent increase following the introduction of the 2D EEMT equipment. Furthermore, this effect was apparently not dependent on the level of student ability as defined by prior ET School achievement.

Scores from the Primary Power Unit Test—a paper-and-pencil, multiple choice, declarative knowledge test--were also examined. A 3x3 ANOVA showed a significant effect of student ability level [$F(2,207) = 15.22$, $p < .001$]. The main effect of equipment availability and of ability by equipment interaction were not significant. This finding was not unexpected in view of the troubleshooting nature of the 2D EEMT lessonware and the factual nature of the Unit Test.

Discussion

The results of Study 1 indicated that use of the 2D EEMT improved the performance of ET School trainees as measured by the hands-on troubleshooting test. However, since both EEMT Conditions (2 and 3) performed equally well, it is tentatively concluded that the locus of this effect was in the availability of the 2D EEMT for extra study/remedial training. Introduction of the EEMT into the Primary Power laboratory, Condition 3, did not result in an additional performance increment as compared with Condition 2. The most likely explanation for the superior performance of students in Conditions 2 and 3 is that the 2D EEMT provided an opportunity for additional troubleshooting training during extra study/remediation that was not available to conventionally trained students. Also, since the EEMT was primarily used in an individual training format, students who trained with it may have been better prepared for the individually administered PT.

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[1]Estimates of difficulty for each administration were computed using the mean score for each problem based on all tests administered to date and the number of students who worked each problem during the particular time period. The resulting estimates were 83.3, 82.3, and 82.3 for Conditions 1, 2, and 3, respectively. It was not possible to directly associate particular students with particular Performance Test problems.

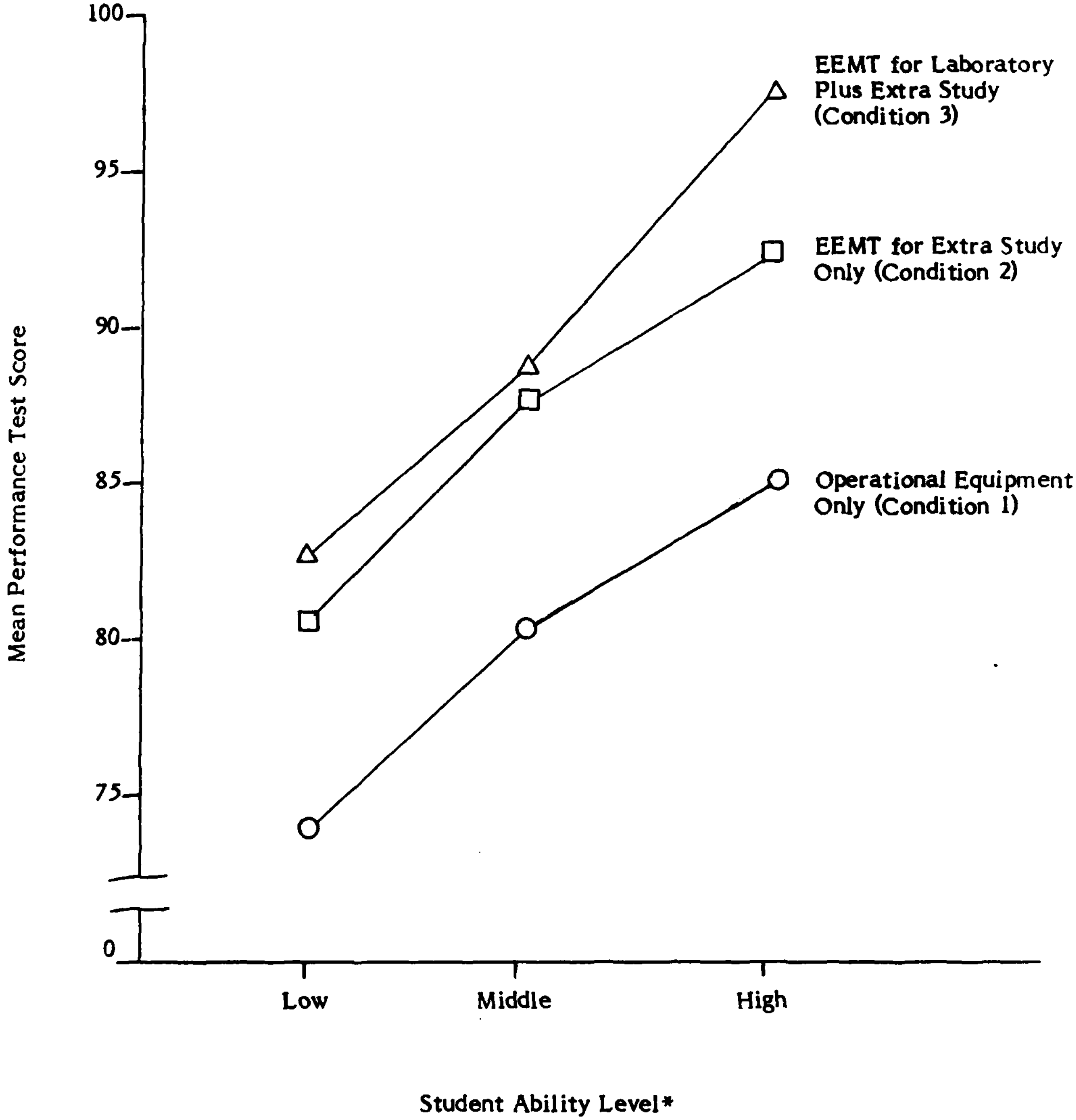

Figure 3. Primary Power radar Performance Test results as a function of student ability levels and training equipment availability for historical data samples.

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*Defined by mean ET School cumulative performance prior to Primary Power radar training.

The finding that students trained during the two time periods when the 2D EEMT was available (Conditions 2 and 3) performed equally well suggests that the EEMT can reduce reliance on operational prime equipment. Since the only training difference between these Conditions was the use of the 2D EEMT during the AN/SPS-10 laboratory, students in Condition 3 received some training on the 2D EEMTs that would normally have been provided via operational equipment without any decrement in PT performance. It must be considered, however, that the extent to which the EEMTs were actually used for laboratory training is unknown. Thus, the extent to which the EEMTs reduced reliance on operational equipment is also unknown, although it is assumed to be relatively slight.

Finally, the results support the hypothesis that the 2D EEMT improves the performance of low, middle, and high ability students. Students of all three ability levels were affected equally by the availability of the 2D EEMTs. The next study in this section was conducted to provide a more rigorous examination of the effects suggested by Study 1.

An additional factor to be considered with respect to these findings is the substantial student backlog problem that existed at ET School at the time the EEMT was introduced. In fact, acquisition of the EEMT units was in part a response to the need for increased student flow to alleviate the backlog and the large class sizes that were associated with it. Since large class sizes may have resulted in higher than optimal student-to-equipment ratios in the training laboratory, the need for laboratory related extra study may have been heightened, and thus the impact of the 2D EEMTs exaggerated.

Study 2: Effectiveness of the 2D EEMT as a Supplement to Operational Equipment Trainers

The overall objective of this study was to determine the impact of incorporating the 2D EEMT into the existing ET School laboratory and extra study/remediation curricula. Given this overall objective, the study addressed the following six hypotheses:

- The 2D EEMT system improves the performance of ET trainees when employed for laboratory and remedial instruction of electronics maintenance training.
- Use of the 2D EEMT system results in a 10 percent increase in student performance as compared with conventional training.
- The 2D EEMT system can maximize the effectiveness of individual hands-on maintenance training.
- The 2D EEMT system can maximize the effectiveness of hands-on maintenance training when delivered using the traditional student team approach.

- The 2D EEMT system improves the performance of low, middle, and high ability students.

- The 2D EEMT system reduces reliance on operational prime equipment in ET training.

Method

Both the training mode and format of Primary Power training were manipulated for students participating in Study 2 of the TCT. The resulting experimental design is illustrated in Figure 4.

Training Mode \ Training Format	Individual Students	Pairs of Students
High EEMT Supplement	Group IH	Group PH
Low EEMT Supplement	Group IL	Group PL
Operational Only	Group IO	Group PO

Figure 4. Experimental groups for Study 2.

Training modes. Student training modes were defined by the extent to which 2D EEMT equipment was used to supplement a student's laboratory and extra study/remediation training. Three modes were selected for study: an Operational Only mode in which all laboratory training was conducted using operational AN/SPS-10 equipment, a Low EEMT mode in which the EEMT was used for approximately 30 percent of laboratory training, and a High EEMT mode in which the EEMT was used for approximately 60 percent of laboratory training. The total amount (hours) of laboratory training was the same for all these modes. Students in the High and Low EEMT conditions were also allowed to use the EEMT for extra study; students in the Operational Only condition used conventional workbooks for extra study training.

Training time on operational equipment was monitored and controlled by ET School personnel and is summarized in Table 2 for the three training modes used in Study 2. Overall, High EEMT students averaged 2.78 hours and Low EEMT students averaged 4.59 hours of training on operational AN/SPS-10 equipment during the 7-8 hours of laboratory training. Although Table 2 shows that Operational Only students averaged 6.24 hours on operational equipment, this figure is an underestimate because student training times were monitored only up to 7 hours. Thus, actual training times were relatively consistent with those specified by the research design for High EEMT, Low EEMT, and Operational Only modes.

The number of problems completed by students in the different training conditions was also monitored by ET School personnel and is summarized in Table B-2 of Appendix B. Because the solution times for training problems varied widely across both problems and students, each training mode actually included a range of troubleshooting experience. Overall, students assigned to EEMT conditions completed slightly more problems during laboratory training (8.30 on the average) than those assigned to Operational Only training (7.55). In addition, EEMT students completed an average of 1.16 problems during extra study/remediation while students in the Operational Only conditions completed only workbook exercises.

Training formats. Two different training formats were employed, individual and pair. Students trained in an individual format worked all laboratory and extra study problems alone; those assigned to the pair format worked all laboratory problems with another student but were allowed to attend extra study on their own. Students trained in either format were provided equivalent amounts of operational equipment training time overall. As shown in Table 2, actual operational training times did not differ appreciably between students in individual and pair formats, averaging 4.40 hours and 4.20 hours, respectively. However, students assigned to the pair-training format were able to complete slightly more problems, both on EEMT and operational equipment, than those assigned to the individual format as shown in Table B-2 of Appendix B.

Subjects. A total of 157 non-nuclear ET students was randomly assigned to one of six experimental conditions defined by crossing the three levels of training mode (High EEMT, Low EEMT, and Operational Only) with the two training formats (individual and pair). Assignments were mixed within classes so that the effects of instructors, training shifts, and test problems were counterbalanced. Subsequent to ET School graduation, each student's academic record was also reviewed to obtain information related to student ability.

Results

Even though students were assigned randomly to experimental conditions, the question of whether students in various conditions were of equal ability was examined to ensure uniformity of group characteristics to the research design. Cumulative ET School achievement scores prior to radar training were submitted to a 3x2 ANOVA (three levels of training mode by two levels of training

Table 2

Laboratory Training Received on Operational Equipment
as a Function of Training Mode and Format

Training Mode		Training Format Individual	Pair	Overall
High EEMT Supplement	N	27	24	51
	$\bar{X}$	2.74	2.84	2.78
	σ	0.43	0.25	0.36
Low EEMT Supplement	N	28	27	55
	$\bar{X}$	4.81	4.36	4.59
	σ	0.93	0.88	0.92
Operational Equipment Only	N	16	16	32
	$\bar{X}$	6.50*	5.98*	6.24*
	σ	0.67	1.09	0.93
Overall	N	71	67	138
	$\bar{X}$	4.40*	4.20*	4.30*
	σ	1.62	1.43	1.53

*Because training time was only aggregated to a maximum of 7 hours, these values may be slightly underestimated.

format). No significant differences among groups were found. Thus, students assigned to each of the six conditions were of comparable ability.

Performance test results. PT scores were the primary measure of training effectiveness and are summarized in Table 3 as a function of training mode and format. Mean scores were 82.59, 78.63, and 80.11 for High EEMT, Low EEMT, and Operational Only conditions, respectively; 79.64 for individuals and 81.11 for pairs. A 3x2 ANOVA conducted on these data revealed no significant main effect of either factor and no significant mode by format interaction.

Times to completion for PTs as shown in Table 4, were also analyzed. Mean times to completion were 31.70, 35.66, and 29.57 minutes respectively for High EEMT, Low EEMT, and Operational Only conditions. Individually trained students took an average of 31.41 minutes and pair-trained students took an average of 34.19 minutes. When these data were submitted to a 3x2 ANOVA, a significant main effect of equipment mode [$F(2,141) = 3.76, p < .05$] and a marginally significant effect of training format [$F(1,141) = 3.41, p < .1$] were found. The mode by format interaction did not approach significance.

Closer examination of the data in Table 4 suggested that these effects might be accounted for by the particularly slow PT completion times of students assigned to Group PL (rf. Figure 4). Further comparisons confirmed that (1) Group PL students were significantly slower than those in Group IL [$t(51) = 2.13, p < .05$] and (2) Group PL students were significantly slower than students in Groups PH and PO combined [$t(70) = 3.04, p < .01$]. However, the reason for the unusually slow performance of Group PL students is unclear. One possibility is that because the 2D EEMT was designed as an individual trainer, it may not be well suited to the pair training format and students who used it in pairs were at a disadvantage. However, this explanation would suggest that students in Group PH would be even more disadvantaged since they received more pair training on the 2D EEMT. This was not found to be the case. Another, and more likely, possibility is simply that EEMT training modes and the pair format are the conditions that are least similar to the PT testing conditions. Unfortunately, this does not explain why Group PL students performed slower than Group PH students either. One final possibility is that familiarization with the EEMT equipment took longer for pairs than individuals. If this was the case, and it is assumed that truly effective training only takes place once students are familiar with a training device, it could be argued that students were not given sufficient EEMT experience in the Low EEMT condition for optimum training effectiveness.

Overall, then, while troubleshooting accuracy was not influenced by the equipment training mode or training format, the speed of troubleshooting was somewhat affected. Specifically, students trained on operational equipment appeared faster than those who received 2D EEMT training, and students trained as individuals were slightly faster than those trained in pairs.

Instructor ratings. Instructor ratings of student AN/SPS-10 laboratory performance (rf. Table 5) were also collected (using a four-point scale) and analyzed using the 3x2 ANOVA approach. A marginally significant main effect of equipment training mode [$F(2,131) = 2.47, p < .1$] was revealed. Further analysis

Table 3

Performance Test Scores as a Function of Training Mode and Format

Training Mode		Training Format: Individual	Training Format: Pair	Overall
High EEMT Supplement	N	25	22	47
	$\bar{X}$	82.51	82.68	82.59
	σ	15.02	14.77	14.74
Low EEMT Supplement	N	26	27	53
	$\bar{X}$	79.99	77.32	78.63
	σ	20.44	26.22	23.38
Operational Equipment Only	N	23	24	47
	$\bar{X}$	76.11	83.93	80.11
	σ	23.97	18.86	21.64
Overall	N	74	73	147
	$\bar{X}$	79.64	81.11	80.37
	σ	19.93	20.84	20.33

Table 4

Times to Completion (in Minutes) for Performance Test as a Function of Training Mode and Format

Training Mode		Training Format: Individual	Training Format: Pair	Overall
High EEMT Supplement	N	25	22	47
	$\bar{X}$	30.80	32.73	31.70
	σ	9.53	11.09	10.22
Low EEMT Supplement	N	26	27	51
	$\bar{X}$	32.04	39.15	35.66
	σ	13.11	11.15	12.56
Operational Equipment Only	N	23	24	47
	$\bar{X}$	29.17	29.96	29.57
	σ	12.67	9.38	11.00
Overall	N	74	73	147
	$\bar{X}$	30.73	34.19	32.45
	σ	11.77	11.17	11.57

Table 5

Instructor Ratings* of Student Laboratory Performance as a Function of Training Mode and Format

Training Mode		Training Format		
		Individual	Pair	Overall
High EEMT Supplement	N	24	20	44
	$\bar{X}$	2.29	1.75	2.05
	σ	1.04	0.55	0.89
Low EEMT Supplement	N	25	23	48
	$\bar{X}$	2.12	1.74	1.94
	σ	0.97	0.86	0.93
Operational Equipment Only	N	22	23	45
	$\bar{X}$	1.91	1.35	1.62
	σ	1.11	0.49	0.89
Overall	N	71	66	137
	$\bar{X}$	2.11	1.61	1.87
	σ	1.04	0.68	0.91

*Rating Scale: 1 = top quarter of students, 2 = second quarter, 3 = third quarter, 4 = last quarter.

showed that students who trained only on operational equipment were rated as superior (mean rating = 1.62) to those who trained on the 2D EEMT (mean rating for High EEMT and Low EEMT students combined = 1.99). The ANOVA also revealed a significant main effect of training format [$F(1,131) = 10.72$, $p < .001$]. Students who worked in pairs were rated superior in performance to those who worked individually (mean ratings = 1.61 and 2.11, respectively). The interaction of training mode and format was not significant. Thus, instructor ratings were highest for students assigned to conventional training conditions, i.e., operational equipment mode and pair format.

Training effects and student ability. In order to examine the effects of 2D EEMT training on low, middle, and high ability students, equal numbers of students were assigned to each of the three ability levels on the basis of prior ET School achievement as in Study 1.[2] Assignments were collapsed across training formats and Primary Power PT scores were then analyzed in the resulting equipment mode by ability level framework. Table B-3 in Appendix B summarizes the findings. A 3x3 ANOVA revealed a significant main effect of ability level [$F(2,138) = 8.08$, $p < .001$] but no significant effect of training mode and no significant interaction. Thus, while PT scores varied as a function of ability level, the PT scores of students at different ability levels were not affected by training modes.

A similar analysis of PT completion times was also conducted. In addition to the marginally significant effect of training mode noted earlier, no significant effects of ability level or ability by mode interaction were found. Apparently PT completion times were more closely related to familiarity with the testing conditions than to students ability levels.

Finally, instructor ratings were submitted to a 3x3 ANOVA which showed significant main effects of equipment mode, as discussed previously, and ability level [$F(2,128) = 3.27$, $p < .05$]. Again, the mode by ability interaction was not significant.

In summary, then, while all three performance measures were related to student ability, the performance of students at each level was not differentially affected by the extent to which their training included use of the 2D EEMT equipment.

Discussion

Unlike Study 1, this study found no appreciable differences among students' PT performance as a function of training mode. The hypothesis that

[2]The mean cumulative ET School averages for low, middle, and high ability students were 84.61, 88.00, and 91.76, respectively. While these scores were somewhat higher than the corresponding scores from Study 1, this difference may have resulted from changes in PT scoring methods rather than qualitative changes in student ability.

EEMT training improves performance was not supported. Because of the historical nature of Study 1, certain training and performance data were not available that may have helped resolve this apparent discrepancy in training effectiveness. For example, training format, extent of laboratory and extra study EEMT use, and PT completion times may have differed substantially between Study 1 and Study 2 students. Another possible explanation follows from the suggestion that the effects of EEMT training in Study 1 might have been magnified because of the student backlog problem. Since training time was controlled in Study 2, no similar effect would be anticipated.

Although training effects were observed for PT completion times in Study 2, they were primarily attributable to the slow performance of students assigned to the Low EEMT/pair conditions. The reason for this is not clear, but is most likely related to a familiarity with the PT testing conditions. That is, students who had more experience working on the operational equipment or working as individuals were faster in the individual operational equipment testing situation.

Instructor ratings clearly favored students in conventional training conditions (operational equipment mode and pair format) over those in EEMT training conditions. However, these data may reflect a preference for existing training practices or perhaps an inability to make accurate ratings under unfamiliar training conditions.

The findings of Study 2 do suggest that the 2D EEMT can reduce reliance on operational equipment in ET training when used as a training supplement. Specifically, based on the High EEMT conditions, it appears that half of the operational equipment laboratory training can be replaced by 2D EEMT training without a decrement in student troubleshooting accuracy as long as EEMTs are also available for extra study/remediation purposes.

Study 3: Follow-up of EEMT-Trained Students

The objective of this study was to examine the long-range impacts of EEMT "A" School training. Specifically, this follow-up effort focused on the need for refresher training during "C" School or fleet assignments and the generalizability of EEMT training to the larger population of electronic equipment. The primary hypotheses to be addressed are:

- Use of the EEMT for ET "A" School training does not result in subsequent increased refresher training needs.

- The skills and knowledge learned on the EEMT system generalize to the larger population of equipments maintained by ETs.

The ability of a follow-up study to detect long-range EEMT effects is related to two factors: the strength of the EEMT training intervention and the

length of time between that training and the follow-up. Thus, this study was designed to focus on students who received the greatest amounts of EEMT training and examined immediate as well as long-range impacts.

Method

Students who participated in Study 2 also served as the subjects for this experiment. Immediate refresher training needs (i.e., "A" School remediation and setbacks) were tracked as part of the review of student ET School records. A sample of the students was also tracked to "C" School or advanced training programs. Due to the large number of possible "C" School assignments, only those programs to which a significant number of students were assigned were contacted. Performance at the "C" School assignment was assessed after a 1 to 2 month period of advanced training. A one-page questionnaire (see Section A-1 of Appendix A) was distributed to the immediate training supervisor of each of the technicians.

Results

"A" School refresher training needs. ET students who fail a PT are assigned to compulsory remediation prior to retaking the failed test. The proportion of students who fail the Primary Power and subsequent radar PTs, therefore, is a direct measure of the need for "A" School refresher training. These values were computed using scores obtained from student records and are summarized in Table 6. Overall, the proportion of students requiring compulsory laboratory-related remediation was relatively low (less than .20) during each of the four radar training areas.

After combining the two EEMT training conditions, these data were submitted to independent 2x2 Chi-Square analyses for each training area. No significant differences in the proportions of students assigned to compulsory remediation were found as a function of EEMT vs. conventional training.

"C" School follow-up. Follow-up questionnaires were completed by "C" School supervisors for 98 students who had participated in Study 2. Table B-4 of Appendix B summarizes their ratings with respect to the seven questionnaire items for students in each of the three "A" School training modes. Mean ratings were slightly above average for every item (the range was from 3.30 to 3.39) and did not differ as a function of training.

Discussion

The follow-up of EEMT-trained students supported the hypothesis that use of the trainer does not result in subsequent increased refresher training needs either at the "A" or "C" School levels. This was not surprising in view of the

Table 6

Proportion of Students Assigned to Compulsory Laboratory-Related Remediation During Radar Training

Training Area	TCT Training Mode		
	High EEMT (N=43)*	Low EEMT (N=51)*	Operational Only (N=49)*
Primary Power	.05	.14	.10
Transmitters	.16	.20	.18
Receivers	.14	.20	.15
AN/SPA-25	.14	.13	.20

*These values vary slightly for some cells of the matrix because of attrition and missing data.

relatively minor training manipulations employed in Study 2. Comments from the follow-up questionnaires, structured interview findings, and comments from student follow-up interviews[3] supported the hypothesis that the tasks, skills, and knowledge learned on the EEMT system generalize to the larger population of equipment maintained by ETs, at least to the same extent as those learned on operational AN/SPS-10 equipment. A transfer of training paradigm would be needed to address this issue of generalizability in a more direct and comprehensive fashion.

Summary

Analysis of the training effectiveness of the 2D EEMT both during and after the Primary Power area of AN/SPS-10 radar instruction indicates:

- When used for a limited laboratory and extra study instruction, the 2D EEMT does not significantly improve the performance of ET trainees.

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[3]Informal "C" School interviews were conducted at Lowry Air Force Base, Denver, Colorado, with a small sample of TCT participants.

- When used in conjunction with operational equipment, the 2D EEMT system can reduce reliance on operational equipment by 50 percent in a training laboratory setting.

- Use of the 2D EEMT is equally effective for low, middle, and high ability students.

- The 2D EEMT is an effective alternative to the use of operational equipment for providing extra study and remediation opportunities.

- Use of the 2D EEMT for ET "A" School training does not result in subsequent increased refresher training needs.

- The skills and knowledge learned on the EEMT system generalize to the larger population of equipment maintained by ETs.

IV. OPERATIONAL SUITABILITY

The evaluation plan of the operational suitability of the 2D EEMT system for ET "A" School training was developed to address a wide range of system-related issues: reliability, availability, maintainability, appropriateness for Primary Power training, adaptability to other training areas, and user acceptance. Specific hypotheses addressed include:

- There are a sufficient number of spares to repair all critical or major failures during the evaluation period.
- The EEMT is available for training at least 90 percent of the time.
- The EEMT incorporates basic safety principles.
- Person-equipment interface features maximize efficient safe operation and maintenance of the 2D EEMT.
- The 2D EEMT system is easily transported, assembled and disassembled.
- The 2D EEMT system is compatible with the ET "A" School environment.
- Performance data from the 2D EEMT system are interoperable with the Navy CMI system.
- The 2D EEMT can adapt to changing job demands.
- Training requirements for 2D EEMT operations and maintenance personnel are within specified limits.
- The 2D EEMT can be used to train to appropriate vacuum tube, solid state, and LSI technology.
- The 2D EEMT can be maintained and logistically supported by Navy personnel at ET "A" School.
- The 2D EEMT will allow an increase in the student-instructor ratio.

Reliability

Unscheduled maintenance activity was tracked to determine the reliability level of the 2D EEMT units. Reliability was defined as the extent to which the 2D EEMT units allocated to the Primary Power training required unscheduled maintenance during the TCT period. The approach taken to measure

the reliability of the units included in the study was to review the ET "A" School Support Division Daily Production Reports (DPR) for the period 13 June 1983 through 9 September 1983, the DRI Training Availability forms, the Support Division Down Equipment Daily Logs and structured interviews with ET "A" School personnel (rf. Section A-4 of Appendix A).

The DPRs for this period revealed that the 18 units assigned to Primary Power training (laboratory and extra study/remediation) required a total of 118 individual repair actions. The actions counted do not include scheduled equipment maintenance, failures corrected by laboratory instructors at the time of the event, or instances in which malfunctions were reported by laboratory instructors but could not be duplicated by the maintenance technician. To provide a more detailed account of system reliability, the frequency of various types of problems is presented in Table 7.

One problem identified by ET "A" School personnel and students, but not reflected in maintenance data, was the EEMT system lockup. During lesson operation, the 2D EEMT would "freeze" at a random point in the lesson. While the system could be restarted by the instructor, student progress in troubleshooting and the student performance record were lost. Since the lockup problem did not require maintenance personnel intervention, incidents of system lockup were not recorded on DPRs. Although the frequency of system lockup was not recorded, the problem was considered particularly frustrating (as reflected in the User Acceptance analysis) due to the need to restart and the loss of the student performance record. Support Division personnel suggested heat buildup within the 2D EEMT system as a possible cause of the lockup problem. The placement of the videodisc player and the microprocessor in the console cabinet (rf. Figure 1) did result in heat buildup due to insufficient air ventilation/circulation. Nevertheless, no direct connection was made during the TCT between heat buildup and system lockup. These problems were being addressed by manufacturer and Support Division personnel at the end of the TCT.

Maintenance Material Management (3M) reports for the AN/SPS-10 Primary Power laboratory equipment for the report period January 1983 through September 1983 were reviewed. They showed 16 repair actions to this operational equipment. All repair actions to AN/SPS-10 equipment are the responsibility of RCA personnel.

<u>Summary</u>

The results of the equipment reliability analysis indicate:

- Unscheduled maintenance actions on the 18 2D EEMT units numbered 118 during the TCT. A total of 16 unscheduled maintenance actions on the operational AN/SPS-10 were required during a somewhat longer period of time.

- Maintenance actions related to touch panels for the 2D EEMT units included in the TCT accounted for a total of 46 of 118, or 40 percent, of recorded maintenance actions during the study period.

Table 7

2D EEMT Maintenance Actions
(13 June to 9 September 1983)

Component/Action	Number of Occurrences
12" CRT:	
*Retape touch panel	14
*Replace touch panel	10
Calibrate x,y origin and gain	13
19" CRT:	
*Retape touch panel	14
*Replace touch panel	0
Calibrate x,y origin and gain	15
Degauss	1
Repair chassis	3
Videodisc Player:	
Repair	5
Altos Microprocessor:	
Replace CPU board	2
Replace video RAM	1
Replace PIA board	10
Replace boot switch	3
Replace disc drive cable	1
Unspecified malfunction	1
Miscellaneous:	
*Constant contact on touch panel	2
Adjust screen voltage and bias	1
Replace cable between LDP and Altos	1
Check operation and calibration	10
*Check touch panel alignment	3
Adjust color and brightness	1
*Adjust reference	3
Intermittent lockup	4
Total repair actions	118

*Related to touch panel maintenance actions. Total number equals 46, or 40 percent of total 2D EEMT maintenance actions.

Availability

An important element in the evaluation of a training device is the frequency with which it is available for training when needed. Training availability was assessed by review of the ET "A" School Support Division Down Equipment daily logs and by analysis of the Training Availability forms. Down Equipment Daily Logs list all 2D EEMT components which are inoperable by room location, problem and anticipated date of repair.

Results of the analysis are shown in Figure 5. Specifically, in the period of time during which equipment downtime was tracked (13 June through 9 September), there were 1,224 total unit-operating days (68 classroom days x 18 units). Of these, there were 338 down equipment days attributable to the 18 2D EEMT units. The Down Equipment Daily Logs show that the 8 2D EEMT units assigned to the Primary Power laboratory accounted for 23 down equipment days. This results in 4 percent downtime for the units specifically assigned to this laboratory, or a 96 percent availability.

Component swapping among 2D EEMT units was possible and frequently occurred, meaning a system could be operating even if one of its original components was on the Down Equipment logs. Therefore, a more accurate measure of Primary Power laboratory trainer availability was the Training Availability forms. Primary Power laboratory instructors were asked to indicate on the Training Availability forms whether the 2D EEMT units were available for training during their shift on each day of laboratory training. Results of the analysis of the information contained on the Training Availability forms during the period of the TCT reveal that the units allocated to the Primary Power laboratory were available for training 90.8 percent of the time. Specifically, the eight units in the Primary Power laboratory were tracked for 384 unit-training sessions over the 12 weeks of the TCT (8 units x 3 training days per shift x 16 shifts = 384 unit-training sessions)[4]. Downtime accounted for 35.5 unit-training sessions, or 9.2 percent. The Training Availability forms also showed that only one 2D EEMT unit of the 8 units assigned to the Primary Power laboratory was inoperable for an extended period (7 weeks, or over 50 percent of the TCT period), while two of the 10 2D EEMT units assigned to Primary Power extra study/remediation were down for the whole TCT period, and seven of the 10 were down at the end of the TCT period.

Operational equipment availability for training during the TCT was also tracked on the Training Availability forms. Only seven operational equipment unit-training sessions were missed over 480 total unit-training sessions (10 units x 3 training sessions per shift x 16 shifts = 480 unit-training sessions). This results in a 98.5 percent availability rate. None of the AN/SPS-10 units assigned to the Primary Power laboratory were down for an extended period of time.

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[4]Since all three shifts of each class were not necessarily included in the TCT, the shift has been used as the unit of measure.

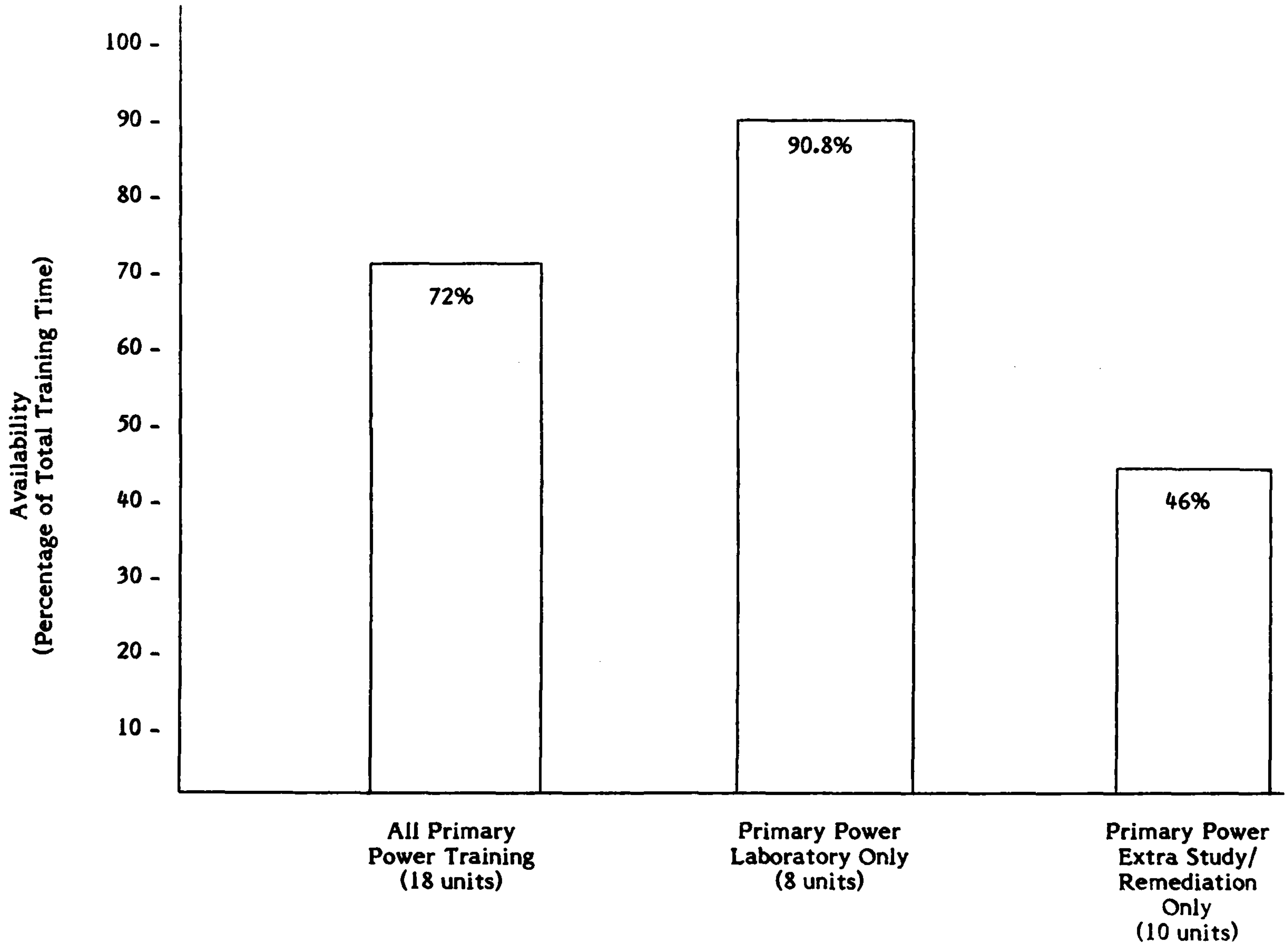

Figure 5. Availability of 2D EEMT Units in Primary Power Training.

Summary

The results of the availability analysis indicate that:

- The 2D EEMT units assigned to Primary Power training were available 72 percent of the required time. This did not meet the 90 percent availability criterion as stated in the DTEMP.

- The 2D EEMT units assigned to the Primary Power laboratory were available for training 90.8 percent of the required time.

- The 2D EEMT units allocated to the Primary Power extra study/remediation laboratory were available for training 46 percent of the time.

Maintainability

This element of the TCT was defined as the ability of the ET "A" School Support Division to provide on-site maintenance support subsequent to contractor training and using existing spares packages. The information required to evaluate the maintainability issue was collected from ET "A" School Support Division Daily Production Reports, Down Equipment Daily Logs, interviews with Support Division personnel and review of maintenance contract commitments and plans.

The extent to which the Support Division personnel were able to complete the 118 corrective actions necessary to maintain and logistically support the 2D EEMT equipment is related to two factors: extent of maintenance training and adequacy of spares packages.

Training

Contractor specifications for maintenance training were identified as 4 weeks of formal training plus on-the-job training (Pine, Daniels, & Malec, 1981). Interviews with ET "A" School Support Division personnel revealed that no formal training program existed for 2D EEMT maintenance training during the TCT. Although a training workshop was conducted by the contractor in November 1982, the workshop emphasized preventive maintenance and was attended by both maintenance and nonmaintenance personnel. Some ET "A" School maintenance personnel who attended the workshop were no longer at ET "A" School by the time of the TCT. Therefore, the Support Division personnel who were responsible for 2D EEMT maintenance during the TCT received only on-the-job training. Since extensive experience and training in general electronics repair is endemic to ET "A" School, Support Division personnel had the skill and confidence to undertake limited in-house maintenance of the 2D EEMT systems and components. For example, faulty boards in the microprocessor were usually repaired in the Support Division workshop. CRT actions were limited to replacement or retaping of touch

panels and calibration. Videodisc player maintenance was confined to swapping units. Actual repairs were performed by authorized commercial shops off-base or by contractor personnel.

Adequacy of Spares Packages

In general the spares inventory available during the TCT was not adequate to meet equipment maintenance requirements. This was due in part to the need to gain experience with equipment malfunction patterns before the optimal spare parts package could be determined. As previously indicated the 18 2D EEMT units assigned to the Primary Power course were available for training 72 percent of the time. Of the eight units assigned to the Primary Power laboratory, much of the downtime was accounted for by only one unit (serial number 5696/11) which was inoperable for approximately 50 percent of the duration of the TCT. These same records indicated that the 10 units assigned to the Primary Power extra study/remediation laboratory were available for 46 percent of the TCT duration overall, with two units (serial numbers 6241/25 and 6015/35) inoperable 100 percent of the time, and 7 of the 10 units inoperable at the end of the TCT period. In almost all cases, inoperability was due to a lack of spare parts rather than a lack of staff capability to effect repairs.

Although spare components for each of the 2D EEMT subsystems were provided by NPRDC prior to the TCT, and contractor delivered spare components were subsequently provided, support personnel ordered parts as needed to effect immediate repairs. The apparent inadequacy of the spare parts inventory can be attributed largely to the high failure rate of 12" touch panels. Spare panels were difficult to obtain and, therefore, were always back ordered. During the TCT, an improved version of the 12" touch panel was introduced to replace the original touch panels. This change, while expected to reduce the number of touch panel failures in the future, commonly resulted in delays of 3 to 6 months in parts availability. A "normal" spares package configuration based on actual classroom performance needs was being reviewed by Navy personnel at the conclusion of the TCT and alternative configurations of and sources for touch panels were being considered.

It should be noted that the ability of Support Division personnel to maintain the Primary Power 2D EEMT units could have been worse except for a pool of "spare" units which was made available because of the TCT. The 20 2D EEMT units assigned to the Communications training area were taken out of service at DRI's request to prevent student contact with the equipment prior to Primary Power training. These "spare" units served as sources of parts during the TCT.

Summary

Results of the analysis of equipment maintainability showed that:

- ET "A" School personnel alone were not able to adequately maintain and logistically support the 2D EEMT during the

TCT. A combination of limited training and lack of needed spare parts resulted in much of the maintenance work being conducted by contract personnel or through agreements with component manufacturers.

- The maintainability of the 2D EEMT system was substantially affected by touch panel malfunctions. These panels were difficult to obtain and were replaced with a newer version which often resulted in delays of 3 to 6 months.

- The development of a more comprehensive spare parts package based on experience with the prototype units and the use of a maintenance contract will substantially improve the maintainability of the 2D EEMT systems.

- The maintenance role of Support Division personnel must be more clearly defined and appropriate training provided accordingly. The fact that Support Division personnel have extensive backgrounds in electronics does not diminish the need for a formal training program.

Appropriateness to Primary Power Training

Two important considerations are the extent to which a trainer meets course training objectives and the ease with which it can be accommodated into the training environment. Appropriateness for training objectives was evaluated by examining the lessonware format and content, considering safety issues, and observing student-instructor ratios. Accommodation to the environment was evaluated by examination of the physical requirements of operating the 2D EEMT system and the transportability of the units from one location to another. A comparison of the AN/SPS-10 and the 2D EEMT on these issues is provided in Table 8. The information necessary to evaluate these issues was obtained from structured interviews with several ET "A" School persons and with Instructional Program Development (IPD) Center persons familiar with the Primary Power training objectives, and review of 2D EEMT documentation.

Training Lessons

Format. According to documentation and instructors who were interviewed, the free-play lessonware, which was developed by the manufacturer, complements and encourages the use of technical manuals, allows students access to areas of the radar equipment which are off limits for training on the operational equipment (due to safety considerations), and trains logical and technical skills well.

Structured lessonware, also developed by the manufacturer for Primary Power training, was not used during the period of the TCT. The structured

Table 8

Appropriateness of the 2D EEMT to
Primary Power Training as Compared to the AN/SPS-10

Category	AN/SPS-10	2D EEMT
Training Lessons:		
Format	Free-play; problem solving	Free-play; problem solving Structured[a]
Content	Primarily wire breaks; meets training requirements	Primarily component failures; meets training requirements
Number of Lessons	Total Primary Power laboratory = 25[b]; In use per AN/SPS-10 = 7	Total Primary Power laboratory = 29; available to each 2D EEMT = 29
Safety:		
Operation	Very poor	Very good
Training	Good[c]	Poor[d]
Student/Instructor Ratio	Approximately 15:1 with laboratory assistant; primarily team training	Approximately 10:1; primarily individualized training[e]
Physical compatibility:		
Power requirements	120 VAC[f]	120 VAC
Air conditioning requirements	Met by existing capacity	Met by existing capacity
Transportability	Very poor	Very good

[a]Tutorial lessonware was not in use during the TCT.

[b]Additional hand-inserted problems on an as-needed basis can increase this pool to approximately 60.

[c]Regular use is seen to increase student respect for operating dangerous equipment.

[d]There are no feedback messages for safety errors; there is no instructor monitoring for safety errors; the system allows unsafe procedures to be performed.

[e]Only reflects TCT period.

[f]Power is stepped up internally in the equipment to 20,000 volts.

lessonware was lengthy, inflexible in application, and was never modified to reflect changes in the picture base. Specifically, each structured lesson could require hours to complete, whereas free-play lessons could be completed in minutes. In addition, the structured lessonware was linear in format; a student was required to complete the entire lesson once he or she began the lesson. There were very few students who required training or additional work in an entire subject area; rather, students usually required extra work on specific elements which were addressed more appropriately by free-play lessonware. Finally, as modifications to the picture base were made, the capability to make modifications to the structured lessonware to reflect those changes did not exist; therefore, the structured lessonware was quickly out of date.

Content. Appropriateness to vacuum tube, solid state, and LSI technology training was determined to be relevant for Primary Power training only with respect to vacuum tube technology training. The free-play lessonware was seen to be effective in meeting vacuum tube training needs. Solid state and LSI technology training is appropriate to other areas of AN/SPS-10 training. The appropriateness of 2D EEMT lessonware to these training needs was not examined during the TCT. The free-play lessons emphasize component repair; this emphasis complements operational equipment lessons which emphasize wire repairs.

Safety

Several comments were made regarding the issue of safety training. The person-equipment interface was seen to be much safer with the 2D EEMT system than with the operational AN/SPS-10 trainers. Students were encouraged in the 2D EEMT laboratory to use the eraser end of a pencil to touch the screens to ensure adherence to basic safety procedures, i.e., keeping hands out of high voltage areas. Several criticisms were leveled, however, regarding the extent to which the lessonware addressed basic safety principles.

The ET "A" School has a significant safety problem because of the high voltages in use with the Primary Power radar equipment. For this reason, certain parts of the Primary Power radar equipment are off limits to students during laboratory training. One advantage to the 2D EEMT lessonware is that it permits student access to these areas through the picture base, allowing a more comprehensive understanding of the equipment. Unfortunately, the lessonware also permits students to take in-line voltage measurements and perform other actions which are not in compliance with safe operating procedures. In addition, there is no aural or visual feedback to the student or the instructor when a safety violation has occurred. One laboratory instructor indicated that although it was possible to restrict student access to specific areas of the picture base, the required programming was too complex to undertake. The individual training format of the 2D EEMT may also have contributed to the problem since the team approach used with operational AN/SPS-10 equipment encourages one student to monitor the activities of the other student and help prevent violations of the safety rules. Finally, students who commit safety violations in the laboratory are required to serve as safety monitors during other laboratory training shifts. These students act as additional protection against safety violations in the laboratories. These students were not assigned to perform this function for the 2D EEMT equipment during the TCT period.

Student-Instructor Ratio

The student-instructor ratio was not manipulated during the TCT. It did fluctuate, however, during the TCT period. The student-instructor ratio was increased due to increased class size to reduce a training backlog. However, separate instructors for operational laboratory and 2D EEMT laboratory training lowered the student-instructor ratio. Despite these fluctuations, the use of 2D EEMT units has the potential to increase the student-instructor ratio for the following reasons:

1. Operational equipment laboratory instructors were often unfamiliar with operation of the 2D EEMT. Once ET "A" School instructors become familiar with 2D EEMT operation, the need for a separate 2D EEMT laboratory instructor could end.

2. 2D EEMT touch panel problems and system lockup occurrences necessitated the presence of a 2D EEMT knowledgeable person to effect immediate repairs when possible. Comments received from instructors and students indicated that the absence of 2D EEMT knowledgeable persons in extra/study remediation laboratories often resulted in 2D EEMT units being taken out of use for minor problems. Correction of problems associated with touch panels and system lockup would reduce the need for separate 2D EEMT laboratory instructors.

3. The reduced risk of injury with 2D EEMT use reduces the need for performance monitoring to the degree required in the operational equipment laboratory. Implementation of oral or visual feedback or use of student safety monitors could address adherence to safe operating procedures without adding additional instructor responsibility.

4. The 2D EEMT units in Primary Power laboratory training were used only during 3 of the 4 days of laboratory training and were not fully utilized then. More efficient use of the 2D EEMT (increased student contact time) could allow an increased student/instructor ratio.

5. Current Primary Power laboratory configurations require separate, although adjacent, interconnected rooms for AN/SPS-10 and 2D EEMT equipment. This arrangement necessitates two instructors. Rearrangement to permit visual monitoring by one instructor could increase the student-instructor ratio.

No formal evaluation of the student-instructor ratio issue was undertaken during the TCT, nor were any of these recommendations implemented. During the TCT,

the Primary Power 2D EEMT laboratory student/instructor ratio was usually 8:1 since there were eight 2D EEMT units in that laboratory. Except for TCT-required team training, most students worked individually. The operational equipment laboratory student/instructor ratio ranged from 15-20:1 depending on the presence of an assistant and/or the classroom instructor. The laboratory instructor was primarily responsible for training and student performance monitoring.

Compatibility to the Primary Power Environment

The 2D EEMT equipment was considered to be compatible with the Primary Power laboratory training environment. The 2D EEMT units were initially housed in existing laboratory space as they were acquired. A portion of an existing electronic equipment testing area (approximately 200 square feet) was later slightly modified to house the Primary Power laboratory 2D EEMT units. No electrical or air conditioning modifications were required.

The 2D EEMT was also compatible with the extra study/remediation laboratory. Ten 2D EEMT units were placed along the perimeter of the two rooms used for Primary Power extra study/remediation. No electrical or air conditioning modifications were made to the rooms to accommodate the units. Students operating the 2D EEMT units, individually or in teams, required little direct interaction with extra study/remediation instructors.

Transportability

The issue of assembly and disassembly as they relate to transportability of the units was only peripherally addressed. Since several additional 2D EEMT systems were purchased and implemented in other training areas after the initial implementation in the Primary Power laboratory, the need to transport the 2D EEMT systems to various locations did not arise. Since the 2D EEMT units were mounted on casters, transportability would not have been a significant problem. The assembly/disassembly issue was indirectly addressed by the maintenance activities of the Support Division. Components of the 2D EEMT systems were removed to the Support Division shop area or swapped among systems to maintain training availability throughout the TCT period. These actions involved movement of components among several different rooms located in two separate buildings. No significant problems were encountered.

Interoperability with the Navy CMI System

The 2D EEMT systems were not directly tied into the Navy CMI system during the TCT. Primary Power laboratory and extra study/remediation laboratory student performance was recorded on floppy disks assigned to the students by the 2D EEMT lab instructor. Through the use of printers located at instructor consoles in the 2D EEMT laboratory, printouts of student performance were obtained and placed in student files. The potential of interfacing the 2D EEMT performance tracking system with the Navy CMI system was not examined during the TCT.

Summary

Analysis of the elements related to the appropriateness of the 2D EEMT to the Primary Power training program revealed that:

- The 2D EEMT free-play lessonware is appropriate to meeting the Primary Power training objectives.
- The tutorial or structured lessonware is too lengthy and inflexible, and has not been modified to reflect changes in the videodisc image base.
- The 2D EEMT system is safer to operate than AN/SPS-10 equipment although there are several weaknesses in the lessonware related to the training of safe operating procedures. These include the capability to take voltage measurements in a manner which does not reflect safe operating procedures and the lack of visual or aural feedback for safety violations.
- The 2D EEMT system is compatible with the existing Primary Power laboratory facilities and is easily transportable through disassembly into component parts.
- The 2D EEMT is easily assembled and disassembled and is highly transportable.
- The data management features of the 2D EEMT were not examined with regard to the Navy CMI system. The features which existed during the TCT were very limited.

Adaptability

The scenarios discussed in this section describe situations in which the 2D EEMT could be used in situations other than the current use in the Primary Power laboratory and in extra study/remediation. The capability of the 2D EEMT to adapt to various changes was considered, and conclusions were drawn based on observation and interviews with ET "A" School and IPD Center personnel.

Scenario 1: Changes in Representative Operational Equipment

The Navy has considered the replacement of the AN/SPS-10 with the AN/SPS-67 in its materials inventory. For the Primary Power laboratory, this would represent a change in the representative operational equipment. Using this potential change as the basis for the scenario, the ability of the 2D EEMT to be adapted to this change was examined.

The hardware and software of the 2D EEMT system would not require modification. Changes to the lessonware and the videodisc image base would be determined by the extent of the differences between the equipments (AN/SPS-10 and AN/SPS-67) and the costs associated with such changes. Several ET "A" School persons are currently competent to author lessons on the 2D EEMT system. Estimates of 3 to 5 weeks of training were given to attain authoring competency, which would not be a significant barrier to developing new lessonware as needed.

Changes in the representative operational equipment could be costly, however, since the cost of incorporating changes to the videodisc may be the same as developing a new disc. Modifications to the videodisc may be limited to adding frames to the videotape master and remastering the disc or may extend to developing a new image base entirely. The capability to develop a new videodisc image base is not currently available at Great Lakes Naval Training Station. The cost of having a new image base developed and a master disk prepared could be extensive.

Scenario 2: Changes in the Instructional Environment

Use of the 2D EEMT in Primary Power laboratory and extra study/remediation has been demonstrated. Use of the 2D EEMT in classroom for demonstration and structured training is considered in this scenario.

Although structured lessonware was developed by the contractor for the initial 2D EEMT implementation, it was not used in training during the TCT because of its length (approximately 8 hours) and the fact that the lessons were not revised to reflect changes in the videodisc image base. Use of structured lessonware in the classroom could assist students in gaining familiarity with the operational equipment and enhance blackboard training procedures. Adaptation of the 2D EEMT to classroom training would not require changes to the hardware, software, or videodisc image base. It would require redesign of the structured lessonware to synchronize it with the videodisc image base. These capabilities exist within the ET "A" School.

Scenario 3: Changes in Personnel Skill Level

The 2D EEMT has been demonstrated at the ET "A" School training level. Its use could be expanded to less skilled areas (e.g., BE&E) or to advanced training areas (e.g., "C" School). These two applications are considered in this scenario.

Less skilled training. Application to a less skilled area would not necessarily require hardware or software changes to the 2D EEMT. Lessonware and videodisc image base changes may be required since the basic electronics training would require generic component images and problems. If the AN/SPS-10 equipment could be considered generic for basic electronics training, some of the existing image base may be appropriate to basic electronics training. Appropriate lessonware would need to be designed for basic electronics. Because the basic electronics training format is currently self-paced, the individualized training format of the 2D EEMT is easily adaptable to this environment.

Advanced training. Application to advanced training areas would not require changes to the hardware and software. Since the AN/SPS-10 is not taught at the "C" School level, changes to the lessonware and videodisc image base would be dependent on: (1) the level of difficulty of existing lessons and (2) the appropriateness of the videodisc image base in representing various levels of detail of other operational equipment.

Scenario 4: Changes in the Physical Training Environment

On-the-job training is a significant part of Navy electronics training. The 2D EEMT could be used to provide and monitor OJT or serve as a performance aid to shipboard technicians. These applications are considered in this scenario.

OJT. The flexibility of the 2D EEMT system, as illustrated in the previous scenarios, suggests that application to OJT in both dock-side and shipboard environments may be feasible. The performance monitoring capability of the 2D EEMT, while not specifically studied during the TCT, may be compatible with the Personnel Qualification System.

However, the 2D EEMT has been demonstrated only in a formal training environment, i.e., in established classroom buildings with in-residence support personnel and access to spares through an established system. The application of the 2D EEMT in dock-side training centers or on ships must be accompanied by the development of an adequate support system.

Performance aid. The objectives of performance aiding are in contrast to those for training. While training requires teaching problem solving skills through practice, performance aiding requires technical information storage and retrieval and problem solving guidance for unspecified malfunctions. For these reasons, the software and lessonware of the 2D EEMT may not be easily adapted to meet the objectives of performance aiding. Revisions to the software would probably require costly modifications. The hardware and image base may not require extensive modifications, assuming the salt water environment and the completeness of the image base in representing the operational equipment are not significant problems.

Summary

Analysis of the adaptability of the 2D EEMT to an alternative training environment suggests that:

- The 2D EEMT is highly adaptable to changes in the representative operational equipment. The primary 2D EEMT modifications required would be to the lessonware and videodisc image base.

- The 2D EEMT is highly adaptable to introduction into the Primary Power classroom. The major system modification

necessary would be development of appropriate structured lessonware.

- The 2D EEMT is adaptable to changes in personnel skill level. Modifications to lessonware and videodisc image base would be required to match the skill level in question.

- While the training approach employed by the 2D EEMT may be adaptable to OJT environments, and for performance aiding in particular, the current configuration of the 2D EEMT would require extensive changes. Therefore, the 2D EEMT is not considered to be easily adaptable to dock-side or shipboard OJT environments.

User Acceptance

The importance of user acceptance in the assessment of training effectiveness of simulators is well demonstrated. This study was designed to assess the extent of user acceptance for the 2D EEMT system within the ET School environment. In particular, this study addressed the following hypotheses:

- Instructors accept the 2D EEMT system as a viable means of providing ET School laboratory and remedial training.

- Students accept the 2D EEMT system as a viable means of providing ET School laboratory and remedial training.

In addition to obtaining user acceptance data, this study provided other supporting information necessary to address some of the training capabilities evaluation questions outlined in the previous studies, especially concerning person-equipment interface, system compatibility with the school environment, hands-on training, and appropriateness of training.

Method

The subjects for this study included all students and instructors that had experience with the 2D EEMT trainer during the course of the TCT. Laboratory, classroom, and remediation instructors were asked to complete a written questionnaire (see Section A-4 in Appendix A) at the close of the evaluation period. Additional on-site structured interviews were conducted by DRI staff with key ET School personnel (Section A-5 in Appendix A presents the interview guide). Written critiques were also administered by ET School personnel to all students participating in the TCT at the end of Primary Power training (rf. Section A-2 in Appendix A).

Instructor Critique Results

Instructor critiques were completed by 48 instructors and training supervisors assigned to the radar branch of ET School. Thirty-two respondents reported using the 2D EEMT equipment as a regular part of radar training and all respondents reported having at least limited EEMT experience.

Based on their experiences with the EEMT, respondents were asked to use a 5-point scale to rate their agreement with statements about simulator training in general. Mean ratings were calculated and are shown in parentheses in the sections that follow. Two-tailed t-tests were then computed for each statement to identify those mean ratings that differed significantly[5] from a noncommittal rating (i.e., 3.00). Of the 10 general statements included, only one drew moderate support: that including simulators in training is a good idea (3.66). Instructors disagreed with 6 of the 10 statements: that simulators can be more effective than actual equipment (1.72), can provide equivalent training with actual equipment (2.20), can provide adequate training at a cost savings (2.32), are more reliable than actual equipment (1.87), teach safety training better than actual equipment (1.30), and provide more variety of training than actual equipment (2.43).

When asked to rate the importance of 13 factors which are considered relevant to simulator design, respondents agreed that all were relatively important. The mean ratings obtained were greater than 3.00 in every case. The most important factors were identified as those with mean ratings significantly greater than 4.00, again using the t-test approach. Four factors met this criterion: the ability to simulate complexity of actual problems encountered in the field (4.30), the capability of Navy personnel to modify existing lessons or create new lessons for the training simulator (4.49), the reliability of performance of the equipment (4.68), and the ease of maintenance of the equipment (4.63).

Respondents also rated their agreement with statements that focused specifically on the free-play troubleshooting lessonware, the authoring software, and the data management aspects of the 2D EEMT system. Mean ratings for 6 of the 10 statements were noncommittal (i.e., did not differ significantly from 3.00); the remaining four statements were not supported. Instructors disagreed with statements that: the EEMT system management does not add significantly to the workload (2.42), student data produced by the EEMT system are helpful in student management (2.42), student data produced by the EEMT system are useful in assessing student abilities (2.36), and the authoring software provides an effective method of developing new lessons (2.39). It should be noted, however, that only five of the respondents indicated having hands-on experience with the authoring software. Because tutorial lessons were not used by ET School personnel during the TCT period, critique data related to those lessons were omitted from analysis. Complete results from the instructor critiques are provided in Table B-5 of Appendix B.

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[5]A .05 level of significance was selected for each comparison.

In addition to critique ratings, 34 of the 48 respondents provided written comments on various aspects of the 2D EEMT system. Eleven instructors believed there was a general need to improve system reliability and nine more noted specific reliability problems (e.g., touch panel drift, system lockup) that interfered with training. Another major concern was the inability of the system to provide appropriate safety training and/or monitor safety-related student errors. Additional comments focused on the need for better representations of test equipment use, improved data management, and expansion of the photographic data base. A frequent remark was that the EEMT is good for remedial/extra study applications but it cannot take the place of the actual equipment for laboratory training.

The results of the Instructor Critiques were substantiated by additional information collected during informal on-site interviews with ET School personnel. Overall, instructors thought that the 2D EEMT could be a useful training supplement to the actual AN/SPS-10 equipment but there were reservations about the current prototype. Their principal concerns can be summarized as follows:

- The system needs improvement in reliability and maintainability.
- The system should incorporate a means of training and monitoring safety procedures.
- Data management features need improvement for easier access to student records and greater data interpretability.
- The free-play lessonware should be improved to provide more assistance to the student and expanded to include the full range of troubleshooting problems.

Student Critique Results

Student critiques were completed by 109 students following their AN/SPS-10 Primary Power laboratory training. This sample included 49 students who were assigned to High EEMT conditions and 48 students who were assigned to Low EEMT conditions. Only 12 students assigned to the Operational Only training mode completed critiques.

Respondents were asked to use a 5-point scale to rate their agreement with statements about the operational equipment training and, if applicable, about the 2D EEMT training they received. Mean ratings were computed and are shown in parentheses. A complete summary of these student critique ratings are provided in Table B-6 of Appendix B. Comments about specific training likes and dislikes were also collected.

The student critique results were examined using three different approaches. First, and most important, a descriptive analysis of student opinions

was performed. The particular focus of this analysis was 2D EEMT training. Second, an analysis of variance approach was used to examine whether student opinions differed as a function of training conditions. Finally, for comparable critique items, matched sample t-tests were conducted to compare operational equipment and 2D EEMT training.

Operational equipment training. Student opinions were consistently favorable regarding operational AN/SPS-10 training. Students strongly disagreed with statements that training time on the equipment was often wasted (1.65) and that equipment breakdowns interfered with training (1.54); they most strongly agreed with statements that they feel comfortable working on the equipment (4.09) and that a variety of training problems were provided (3.97).

Of the eight statements concerning operational equipment training included in the critiques, students disagreed on only two as a function of training conditions. Student ratings of the statement that there was enough training time on the equipment differed significantly among High EEMT (2.76), Low EEMT (3.38), and Operational Only (3.91) conditions [$F(2,98) = 7.31$, $p < .001$]. These groups also differed with respect to a similar statement that more time should be spent on troubleshooting [$F(2,97) = 3.39$, $p < .05$]; mean ratings were 3.85 for High EEMT, 4.00 for Low EEMT, and 3.00 for Operational Only conditions. Thus, while students in all three conditions thought that more hands-on troubleshooting time was necessary, students in EEMT training groups expressed the strongest need.

These findings were further supported by written comments. Seventeen EEMT-trained students indicated that more troubleshooting or hands-on training on the AN/SPS-10 equipment was needed and 11 noted that operational equipment provides the most appropriate training format. Additional written comments expressed the importance of operational equipment training for matters of safety, the desire to see more "nonstandard faults," the belief that paired training could be safer or more efficient than individual training, and the opinion that working individually is more effective than training in pairs.

2D EEMT training. Overall, student responses to the 11 statements that focused on EEMT training were either noncommittal or marginally favorable. Mean ratings of agreement ranged from a low of 2.43 to a high of 3.53 (rf. Table B-7 of Appendix B for a complete listing). Students believed that a variety of lessons was provided (3.49), the trainer was easy to use (3.50) and comfortable (3.36), and that training time was mostly spent in troubleshooting (3.53). There was a significant difference among respondents to this latter statement, however, as Low EEMT (3.27) students were less likely to agree than High EEMT (3.79) students [$t(91) = 2.22$, $p < .05$]. Students disagreed with statements that the lessons were too long (2.43) and that training time on the equipment was often wasted (2.47).

Students were asked to provide written responses concerning their likes, dislikes, and other general comments about the 2D EEMT training. Because of the number and variety of these responses, a complete list of the students' likes and dislikes has been provided in Table B-7 of Appendix B. Two general observations are possible from this table: (1) the dislikes outnumber the likes and (2) many

EEMT system features are included in both lists. The most common student likes were ease of use, comfort, reduced safety risk, availability for practice troubleshooting outside of scheduled laboratory periods, and ability to solve more problems in a given period of time. The most common student dislikes were equipment malfunctions (particularly touch panel drift and EEMT lockup), use of test equipment, inability to access components properly or read test point designations, and the possibility of developing bad safety habits.

The general comments provided by students were far more consistent. Nineteen students remarked that the EEMT is a good training aid but it cannot/should not replace the operational equipment; 13 students thought the EEMT should be used for remediation and extra study; six students preferred more operational equipment training.

Operational equipment vs. 2D EEMT. Four rating items were identical for both the operational equipment and the 2D EEMT training sections of the student critiques. For two of these items, students rated operational training significantly better than 2D EEMT training. Students thought that training time was wasted more on the EEMT (2.48) than on the operational (1.67) equipment [$t(95) = 5.40, p < .001$] and that equipment breakdowns interfered more with training on the EEMT (1.60) than on the operational (2.49) equipment, [$t(94) = 5.91, p < .001$]. With respect to the variety of lessons provided, however, the EEMT (3.94) was rated slightly higher than the operational (3.49) equipment training [$t(88) = 3.18, p < .01$]. This finding was in spite of the fact that students commented on lesson variety as a feature of the EEMT training that they disliked (rf. Table B-7 of Appendix B).

Students believed that the 2D EEMT can be a useful and convenient training aid when used in conjunction with the operational equipment. However, because access to the operational equipment is limited, students prefer to maximize their operational training time during laboratory periods and reserve EEMT training for extra study/remediation settings. The factors which appear most important for further student acceptance are (1) increased system reliability, (2) better incorporation of safety principles, and (3) improved representations of test points and test equipment use.

Summary

Overall, instructors and students were quite consistent in their opinions of the 2D EEMT system. The analysis of user acceptance determined that:

- Both groups identified an important, useful, but limited role for the trainer as a supplement to conventional AN/SPS-10 instruction.
- Extra study/remediation was considered to be the most appropriate setting for the 2D EEMT because it provided more realistic troubleshooting experience than workbooks and required very little instructor supervision.
- Both groups were particularly negative about the low operational reliability of the EEMT (e.g., touch panel problems and system lockup).

V. COST ANALYSIS

The objectives of this component of the TCT were to document the investment, operating, and maintenance costs of the 2D EEMT system and to compare the life cycle costs of the 2D EEMT and operational equipment when used as teaching aids in the Primary Power area of radar systems training at the ET "A" School. The major hypothesis considered in this analysis was:

- The 2D EEMT system provides electronics training at less than half the cost needed to acquire, operate, and maintain conventional operational equipment to accomplish equivalent training (Pine, Daniels, & Malec, 1981).

Additionally, the factors which affect the cost of using 2D EEMT systems are identified and discussed. To illustrate the relationship between the cost of using these trainers and the training environment, the 2D EEMT and the operational equipment were also compared in selected training scenarios.

Method

In order to assure a systematic cost analysis, a basic framework was developed to document and compare the life cycle costs of the 2D EEMT with those of operational equipment. This framework was also used to guide the analysis of various training scenarios in which the 2D EEMT was considered as an alternative or supplemental training aid to current practices.

The cost framework includes five categories: facilities, equipment, instructional materials, instructor and support personnel, and students; the subcategories associated with each major category are as follows:

Facilities

- space to house training devices
- space/utilities modifications required

Equipment

- hardware
- original software development
- system specification and acquisition management
- support and installation of trainers
- sustaining investment for maintenance
- support personnel

Instructional material

- lessonware development and revisions
- training manuals

Personnel

- instructors' wages
- overhead burden

Students

- wages
- billeting and other support

In order to document the life cycle costs of the 2D EEMT, all of the major cost categories were used. Further, since the cost of system design is a nonrecurring cost associated only with the prototype device, this was considered a sunk cost in the life cycle cost analysis. System design costs are, however, presented in Table 9 where prototype, next copy, and an additional copy of the 2D EEMT are compared.

For comparative analyses of 2D EEMT and operational equipment, the assumption of equivalent training effectiveness was made and operating costs were estimated over a 15-year life cycle period. All costs were adjusted using the annual inflation rate to reflect 1981 wholesale commodity prices. To establish net present value (NPV) in 1981 dollars, operating costs were discounted at 10 percent annually in accordance with standard Office of Management and Budget guidelines.

Results

2D EEMT Development and Acquisition Costs

Separate acquisition cost estimates were made for the prototype, first copy, and an additional copy of the 2D EEMT. The cost of the prototype system includes development, design and fabrication. The cost of the first copy of the trainer includes hardware, operating system, and documentation but excludes equipment design and development. The cost of an additional copy is similar to that for the first trainer purchased, except that some cost savings are realized assuming the device is used for the same training application.

The summary of training device cost estimates presented in Table 9 was derived from contract documents supplied by the 2D EEMT contractor and by the Navy Personnel Research and Development Center (NPRDC). Appendix C summarizes contract documents used in this analysis. In some instances, the only cost data available were for aggregated expenditures (e.g., system and user documentation) or included expenditures not considered relevant to the TCT (e.g., 3D EEMT hardware and lessonware). Generally, supporting documentation was used to proportionally allocate aggregated expenditures to the appropriate cost categories. Irrelevant costs were simply noted and eliminated from this analysis.

Hardware costs. Table 9 shows that the cost of the various hardware components is the same for the 2D EEMT copies and the prototype. It is possible,

Table 9

2D EEMT Development and Acquisition Costs
(1981 Constant Dollars)

Cost Categories	Training Device: Prototype 2D EEMT	Training Device: First Copy 2D EEMT	Training Device: Additional Copy 2D EEMT	Cost Notes (rf. Appendix D)
Hardware				
Computer (Altos)	$ 3,620	$ 3,620	$ 3,620	
Laser Disk Player	2,500	2,500	2,500	
12" Monitor (Motorola)	251	251	251	
12" Touch Panel with Bezel	399	399	399	
19" Monitor (RCA)	650	650	650	
19" Touch Panel with Bezel	425	425	425	
Printer (TI Silent 700)	974	974	0	
Station/Console	1,151	1,151	1,151	(A)
System Interfaces/Controllers	1,314	1,314	1,314	(B)
Miscellaneous Materials	250	250	250	(C)
Fabrication	6,777	6,777	6,672	(D)
Development	195,237	0	0	(E)
User Documentation	34,549	1,727	0	(F)
Hardware Total	$ 248,097	$ 20,038	$ 17,232	(G)
Software				
Development	313,836	0	0	(H)
Acquisition	0	50	50	(I)
Software Total	$ 313,836	$ 50	$ 50	
Lessonware				
Development	418,865	125,000	0	(J)
Acquisition	0	637	637	(K)
Lessonware Total	$ 418,865	$ 125,637	$ 637	
Logistics Support				
Spares package	$ 5,162	$ 5,162	$ 5,162	(L)
Total System Cost	$ 985,960	$ 150,887	$ 23,081	

however, that some cost savings might be realized if a sufficient number of trainers were purchased at the same time to obtain a discount on the per unit costs of each component. While the total hardware cost of only the prototype device includes system and user documentation development, the cost of acquiring user documentation already developed is shown as an expenditure associated with the first copy purchased for a specific training application. The costs of an instructor terminal (i.e., printer), its associated fabrication and user documentation are not shown for additional 2D EEMTs. For purposes of estimating the system hardware acquisition cost, it is assumed that the instructor terminal purchased with a first copy of the trainer can support four additional units used for the same training application.

Software and lessonware costs. The costs of software and lessonware were the most difficult to identify for a number of reasons: (1) the term software was frequently used in contract or documentation to refer to both operating system software and lessonware; (2) lessonware was originally developed or proposed to be developed for several ET "A" School areas, including generic and representative equipment; (3) some lessonware was also developed for the EW School at Corry Station, Florida; and (4) software and lessonware were created to support the 3D EEMT systems. Only software and lessonware costs incurred to support training for the Primary Power area of radar training in the ET "A" School at Great Lakes Training Center were considered relevant for the TCT.

The total cost of prototype software shown in Table 8 includes expenditures for government furnished software, initial system software, and software changes made under contract modifications. Total software costs for a first copy and an additional 2D EEMT do not include any development effort and are shown to be limited to the purchase of diskettes. Similarly, the total cost of prototype lessonware is shown to include government furnished lessonware, initial 2D EEMT lessonware, modifications to lessonware strategies and videodisc production. Lessonware cost estimates shown in Table 9 for the first trainer have been made assuming that a typical training application will require the creation of a normal operations free-play data base diskette and about 30 practice problems and the production and mastering of a supporting videodisc. Other expenditures associated with the first copy lessonware include student diskettes, and printer paper. Assuming that additional trainers are purchased with the first unit and used for the same training application, lessonware expenditures are limited to the cost of videodisc and diskette copies and printer paper. Note, however, that videodiscs not purchased in conjunction with the mastering process will require remastering at the cost of $1,700.

Logistics support costs. The cost of logistics support shown in Table 9 was derived from contract documents and includes the spare parts package purchased by NPRDC from the 2D EEMT manufacturer and directly from hardware vendors. These expenditures were allocated across the 20 2D EEMT units acquired under the Basic Contract to obtain the per unit cost. As the number of devices supported increases, it might be expected that some per unit cost savings will be realized.

Total system costs. The results of the cost analysis shown in Table 9 indicate that the design and development of the prototype 2D EEMT was nearly $1

million including government furnished equipment, software and lessonware. Total system costs for the first copy and an additional copy were $150,887 and $23,081, respectively. The difference of $127,086 between the first and additional copies of the trainer is accounted for by two major factors: (1) the instructor terminal (e.g., printer) and related system support and (2) lessonware development. For purposes of estimating future 2D EEMT acquisition costs, it should be assumed that the cost of lessonware development will be incurred only once for each training application and that one instructor terminal (and related costs shown under hardware) will support a total of five 2D EEMT units.

Life Cycle Cost Analysis

Tables 10, 11, and 12 show the life cycle costs associated with the 2D EEMT first copy, an additional 2D EEMT, and the AN/SPS-10 operational equipment, respectively. All initial investment and operating costs are reported in constant 1981 dollars; operating costs are projected over a 15-year period and include expenditures for maintenance, instructional materials and instructor, and student support.

Differences in facilities cost between the 2D EEMT systems (Tables 10 and 11) and the AN/SPS-10 (Table 12) reflect the larger amount of space required to support each AN/SPS-10 unit as compared to a 2D EEMT unit. In general, however, no alterations to existing facilities are required to introduce the 2D EEMT system into a typical laboratory training environment.

With respect to equipment, the cost of 2D EEMT hardware is substantially less than that for the AN/SPS-10 operational equipment. Savings of about 70 percent over the cost of a replacment AN/SPS-10 unit are shown with purchase of either a first copy or additional copy of the 2D EEMT. The higher costs for sustaining investment, maintenance and operation (power requirements) of the AN/SPS-10 also result in savings with the purchase of a 2D EEMT system. This is expected, however, since sustaining investment costs are calculated as a percentage of the initial hardware cost. Maintenance costs reflect actual personnel wages. These costs differ because the AN/SPS-10 equipment is maintained solely under a service contract, whereas the 2D EEMT is maintained by ET "A" School personnel. Lastly, because operating costs are allocated on a per square foot basis, the 2D EEMT is somewhat less expensive to operate than the actual equipment.

The most significant cost difference between the 2D EEMT and the operational equipment is the lessonware development investment cost associated with the 2D EEMT first copy (Table 10). This expenditure reflects the cost of developing a free-play data base and 30 free-play problems used with the 2D EEMT unit in the ET "A" School environment. As Table 11 shows, however, this cost is not incurred with additional 2D EEMTs used for the same training application. The AN/SPS-10 operational equipment life cycle cost (Table 12) does not include an investment for lessonware. The costs of developing the training problems used in the Primary Power radar laboratory were considered as sunk costs and therefore, not estimated. In the exisiting environment, only updating of training problems over the 15-year life cycle was considered necessary. The

Table 10

Life Cycle Costs
for the First Copy 2D EEMT in Constant 1981 Dollars
(Thousands of Dollars)

Cost Category	Cost Element	Inv Cost	Operating Years 1	2	3	4-15	Total	Cost Notes (rf. Appendix D)
Facilities	Replacement cost of space		.75	.75	.75	.75	11.25	(M)
	Supplemental furnishings	0						
Equipment	2D EEMT hardware	20.04					0	rf. Table 8
	2D EEMT software	.05					0	rf. Table 8
	Acquisition management	0					0	(N)
	Sustaining investment	5.16	1.00	1.00	1.00	1.00	15.00	(O)
	Maintenance		.91	.91	.91	.91	13.65	(P)
	Operating costs (power)		.18	.18	.18	.18	2.70	(Q)
Instructional Materials	TOs and/or lessonware	125.62	63.30	63.30	63.30	63.30	949.50	(R)
	Update laboratory exercises		.35	.35	.35	.35	5.30	(S)
Personnel	Laboratory Instructor		18.30	18.30	18.30	18.30	273.70	(T)
	Overhead Burden		10.10	10.10	10.10	10.10	151.50	(U)
Students	Wages		314.80	314.80	314.80	314.80	4,722.00	(V)
	Miscellaneous support cost		363.00	363.00	363.00	363.00	5,445.00	(W)
TOTALS		150.87	772.69	772.69	772.69	772.69	11,589.60	

Total cost in constant dollars = $11,740,470
Net present value (1981) = $6,051,038

Table 11

Life Cycle Costs
for an Additional Copy 2D EEMT in Constant 1981 Dollars
(Thousands of Dollars)

Cost Category	Cost Element	Inv Cost	Operating Years 1	2	3	4-15	Total	Cost Notes (rf. Appendix D)
Facilities	Replacement cost of space		.75	.75	.75	.75	11.25	(M)
	Supplemental furnishings	0						
Equipment	2D EEMT hardware	17.23					0	rf. Table 8
	2D EEMT software	.05					0	rf. Table 8
	Acquisition management	0					0	(N)
	Sustaining investment	5.16	1.00	1.00	1.00	1.00	15.00	(O)
	Maintenance		.91	.91	.91	.91	13.65	(P)
	Operating costs (power)		.18	.18	.18	.18	2.70	(Q)
Instructional Materials	TOs and/or lessonware	.64	63.3	63.3	63.3	63.3	949.50	(R)
	Update laboratory exercises		.35	.35	.35	.35	5.30	(S)
Personnel	Laboratory Instructor		18.30	18.30	18.30	18.30	273.70	(T)
	Overhead Burden		10.10	10.10	10.10	10.10	151.50	(U)
Students	Wages		314.80	314.80	314.80	314.80	4,722.00	(V)
	Miscellaneous support cost		363.00	363.00	363.00	363.00	5,445.00	(W)
TOTALS		23.08	772.69	772.69	772.69	772.69	11,589.60	

Total cost in constant dollars = \$11,612,680
Net present value (1981) = \$5,923,248

Table 12

Life Cycle Costs
for the AN/SPS-10 Radar System in Constant 1981 Dollars
(Thousands of Dollars)

Cost Category	Cost Element	Inv Cost	Operating Years 1	2	3	4-15	Total	Cost Notes (rf. Appendix D)
Facilities	Replacement cost of space		1.20	1.20	1.20	1.20	18.00	(M)
	Supplemental furnishings	0						
Equipment	AN/SPS-10 hardware	58.13					0	(X)
	AN/SPS-10 software	0					0	
	Acquisition management	0					0	Sunk cost
	Sustaining investment	0	2.90	2.90	2.90	2.90	43.50	(O)
	Maintenance		2.16	2.16	2.16	2.16	32.40	(Y)
	Operating costs (power)		.28	.28	.28	.28	4.20	(Z)
Instructional Materials	TOs and/or lessonware	0	63.30	63.30	63.30	63.30	949.50	(R)
	Update laboratory exercises		.35	.35	.35	.35	5.30	(S)
Personnel	Laboratory Instructor		18.30	18.30	18.30	18.30	273.70	(T)
	Overhead Burden		10.10	10.10	10.10	10.10	151.50	(U)
Students	Wages		314.80	314.80	314.80	314.80	4,722.00	(V)
	Miscellaneous support costs		363.00	363.00	363.00	363.00	5,445.00	(W)
TOTALS		58.13	776.39	776.39	776.39	776.39	11,645.10	

Total cost in constant dollars = \$11,703,980
Net present value (1981) = \$5,966,430

reoccurring cost of printing student guides (FOMMs) was estimated to be the same for all training equipment. Instructor and student costs are the same for the 2D EEMT and AN/SPS-10 systems because the two devices were used in a similar manner in the same training environment.

A comparison of the total life cycle costs shown in Tables 10 and 12 indicates that the first copy of the the 2D EEMT system will cost $84,608 more than the AN/SPS-10 operational equipment over the 15-year period in 1981 NPV dollars. Nearly all of this cost difference can be attributed to the lessonware development investment cost for the first copy of the 2D EEMT. Comparison of the total life cycle cost of an additional copy of the 2D EEMT (Table 11) and the AN/SPS-10 operational equipment reveals a savings of $43,182 with the 2D EEMT. Neither of these comparisons, however, is a true reflection of costs. While the lessonware development cost associated with the first copy of the trainer is unavoidable, it is a nonrecurring cost if multiple 2D EEMTs are used for the same training application. In fact, the acquisition of three 2D EEMTs (a first copy and two additional copies) results in a comparable investment, in 1981 NPV, to the acquisition of three AN/SPS-10 units. Each additional 2D EEMT copy acquired at less cost than an additional AN/SPS-10 unit, results in an overall life cycle cost savings of $43,182.

To illustrate this point, consider the ET "A" School environment where 20 2D EEMT units were purchased under the basic contract. Including the cost of the first copy of the EEMT, three trainers with instructor terminals and required support (but excluding lessonware development) and 16 additional units, the life cycle savings over purchase of 20 AN/SPS-10 units is $1,150,804 in 1981 NPV.

These analyses which focus primarily on single units show that the major factor contributing to the potential lower life cycle cost of the 2D EEMT, as compared to operational equipment, is the initial equipment investment. Thus, in training environments where a single operational equipment trainer will be acquired, the initial investment costs must exceed about $143,000[6] or require support or operating expenditures well in excess of those for the AN/SPS-10 if the 2D EEMT is to show a lower life cycle cost estimate. Alternately, if less expensive operational equipment is necessary to support training, the 2D EEMT would show a lower life cycle cost estimate only if multiple units were required or the operational equipment had associated support or operating costs substantially higher than those for the AN/SPS-10.

In sum, examination of the life cycle cost estimates shown in Tables 10, 11, and 12 indicates that acquisition of a 2D EEMT will result in a slightly higher cost for a first copy and a slightly lower cost for an additional copy than the acquisition of an AN/SPS-10 operational unit. When multiple units are needed and investment costs are spread over additional copies, acquisition of the 2D EEMT results in a life cycle cost savings over the AN/SPS-10 when three copies are acquired.

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[6]This estimate was derived by adding the acquisition cost of the AN/SPS-10 and difference in the life cycle costs, in 1981 NPV, of this device and the first copy of a 2D EEMT (rf. Tables 10 and 12).

Considering only initial investment costs, the purchase of 20 2D EEMT units results in a cost savings of approximately 50 percent over the purchase of 20 AN/SPS-10 units. This comparison is based on the assumption that four instructor terminals will be needed to support the 20 2D EEMT units and the one time cost of trainer lessonware will be incurred. Since it was not possible to estimate the cost lessonware acquisition for the AN/SPS-10 units, the estimate of 20 units to attain a 50 percent cost savings is conservative.

Hypothetical Training Scenarios

Since the actual life cycle cost savings that might be realized by employing 2D EEMT units will depend in large part on the training needs and environments in question, the following scenarios are presented to illustrate how the preceding cost data might be used to assist in the equipment acquisition decision making process. Further, because many training environments are similar to that of the ET "A" School at Great Lakes Naval Training Station, four of the examples focus on situations involving the addition or modification of multiple student training stations in this typical environment. The fifth scenario involves transferring this training approach to another environment.

Scenario 1: Comparison of Supplemental Trainer Options

In this scenario, it is assumed that it is necessary to increase the number of training devices to meet an increased demand on the ET "A" School. Table 13 shows the comparison of training costs associated with acquiring 10 additional operational equipment units (AN/SPS-10 or AN/SPS-67) or 2D EEMT units to expand the capability of the Primary Power section of the Radar Systems course. The AN/SPS-67 was selected as a comparative operational system because this radar unit is the most likely replacement for the AN/SPS-10 in the fleet and would probably replace the AN/SPS-10 as the operational equipment trainer in the ET "A" School as well.

The characteristics of the ET "A" School environment were used to establish the parameters of the comparison. First, it was assumed that the existing laboratory housed 10 actual equipment trainers and an additional 10 stations (operational equipment or 2D EEMTs) were needed to manage an increased student flow. Additional trainers for extra study/remediation purposes were not included in this analysis. Second, student flow was assumed to be 66 per class, or approximately 22 students per shift per week. Third, for safety reasons, it was necessary to have one instructor present in the laboratory for every 10 training stations in use.

As shown in Table 13, the life cycle costs associated with adding 10 2D EEMT units in the laboratory training environment are less than those associated with adding 10 AN/SPS-10 units or introducing 10 newer AN/SPS-67 units. The NPV and cost of training per student-hour calculations also indicate a cost savings for the 2D EEMT over both the AN/SPS-10 and AN/SPS-67 options. To illustrate the extent of this potential cost savings, consider a training environment involving

Table 13

Scenario 1: Life Cycle Cost Comparison of Supplemental Trainer Options

Cost Categories	Training Device: 2D EEMT (10 units)	AN/SPS-10 (10 units)	AN/SPS-67 (10 units)	Cost Notes (rf. Appendix D)
Facilities	$ 90,000	$ 180,000	$ 180,000	(M)
Equipment				
Hardware	$ 177,932	$ 581,300	$1,400,000	(AA), (BB)
Software	500	0	0	(I)
Sustaining Investment	201,620	435,000	1,050,000	(O)
Maintenance	136,500	324,000	324,000	(P), (Y)
Operating Costs	27,000	42,000	42,000	(Q), (Z)
Instructional Materials				
TOs/Text Lessons	$1,063,578	$ 949,500	$ 983,089	(J), (R), (CC)
Videodisc Development	10,922	0	0	(J)
Copies	170	0	0	(K)
Diskettes/Printer Paper	6,200	0	0	(K)
Updating	5,300	5,300	5,300	
Personnel	$ 425,200	$ 425,200	$ 425,200	(T), (U)
Students	$10,167,000	$10,167,000	$10,167,000	(V), (W)
Total Cost	$12,311,922	$13,109,300	$14,576,589	
NPV 1981	$6,426,108	$6,939,010	$8,103,317	
Cost per student-hour	$ 60.85	$ 65.71	$ 76.74	

60 students per week. If 10 2D EEMT units were used instead of 10 AN/SPS-10 units, a cost saving of $11,664 per 40 hour week would be realized. The implication of this alternative cost scenario is that 2D EEMT systems, when purchased in multiple copies to meet expanded training requirements, can result in substantial cost savings over the purchase of additional operational equipments.

Scenario 2: Extensive Modification to an Existing Trainer

In this scenario, it is assumed that 10 2D EEMT units have been purchased and implemented in the Primary Power radar training environment. In addition, it is assumed that the existing operational equipment used as trainers (e.g., the 10 AN/SPS-10 units in the Primary Power laboratory) require extensive modifications due to technology changes. Depending on the extent of modifications to the operational equipment, modifications to the 2D EEMT training system may also result. Table 14 shows the estimated cost of modifications to the 2D EEMT if changes in the operational equipment necessitated development of 15 new free-play lessons, redevelopment of technical documentation (FOMMs) and redevelopment of the videodisc image base. This estimate represents the highest 2D EEMT modification cost possible since complete redevelopment of the videodisc image base would not be necessary in all instances. Equipment, facilities, personnel and student costs associated with the trainer would not change.

The costs associated with changes in the operational equipment include equipment modification costs estimated at one-half the cost of new units, plus twice the annual cost of printing technical documentation and instructional materials modification costs estimated at one-half the costs of developing lessonware. Table 14 shows that when operational equipment modifications are necessary, the associated costs could be more than 50 percent if 2D EEMT units were being used in the training environment.

The need for very extensive modifications to the operational equipment could result in replacement of existing operational equipment units with a new operational system, such as the AN/SPS-67. The acquisition costs of 10 of these units was shown in Table 13. The only additional impact of such a replacement to the 2D EEMT units would be full lessonware development (30 free-play lessons) vs. 15 free-play lessons as described earlier. In this situation, modification of the 2D EEMT units would result in dramatic savings over the cost of acquiring new operational equipment.

This scenario illustrates that the decision to acquire 10 2D EEMT units can result in additional savings if replacement or modifications to the existing operational units used for training should be required at a later date.

Scenario 3: Classroom Use

Introduction of the 2D EEMT system into the classroom, e.g., the AN/SPS-10 Primary Power classroom, would result in expenditures for additional trainers and structured lessonware development. These costs are shown in Table 15. Facilities modifications would be minimal and therefore are not considered an

Table 14

Scenario 2: Cost Implications for the 2D EEMT and Operational Equipment due to Extensive Modifications to Operational Equipment

Cost Categories	Equipment Cost 2D EEMT	Equipment Cost AN/SPS-10	Cost Notes (rf. Appendix D)
Facilities	NC*	NC	
Equipment			
Hardware	NC	$290,650	
Software	NC	-	
Sustaining Investment	NC	NC	
Maintenance	NC	NC	
Operating Costs	NC	NC	
Instructional Materials			
TOs/Text Lessons	$183,539	$147,595	(DD)
Videodisc Development	10,922	-	
Copies	170	-	
Diskettes/Printer Paper	NC	-	
Updating	NC	NC	
Personnel	NC	NC	
Students	NC	NC	
Total Cost of Modifications (1981 dollars)	$194,631	$438,245	

*No change from Table 13

Table 15

Scenario 3: Cost Implications of Introducing 2D EEMT into the Classroom

Cost Categories	Cost Implications	Cost Notes (rf. Appendix D)
Facilities	NC	
Equipment		
Hardware	$88,966	(EE)
Software	250	
Sustaining Investment	30,810	
Maintenance	NC	
Operating Costs	NC	
Instructional Materials		
TOs/Text Lessons	$96,525	(FF)
Videodisc Development	1,700	(J)
Copies	85	(K)
Diskettes/Printer Paper	620	(K)
Updating	NC	
Personnel	NC	
Students	NC	
Total Cost of Introduction into Classroom	$218,956	

additional cost. Five 2D EEMT units would be sufficient to meet classroom training objectives since students could be rotated between workbook activities and 2D EEMT lessons. Additional maintenance and operating costs are considered minimal.

Structured lessonware would be more appropriate to classroom use than free-play lessonware, since it focuses on overall AN/SPS-10 operational equipment familiarity rather than the troubleshooting practice. No alterations to the videodisc image base would be necessary for use in the Primary Power classroom. Additional copies of the videodisc, however, would require remastering of the disc. No additional units in extra study/remediation are projected; the shared use of extra study/remediation units for classroom and laboratory extra study/remediation is assumed. However, structured lessonware for use in the extra study/remediation laboratory would be necessary. Costs for duplication of this lessonware would be minimal. Table 15 shows that the total equipment and instructional materials costs of adding five 2D EEMTs to a classroom setting is about $ 218,956.

Introducing operational equipment into the classroom was viewed as an inappropriate use of the equipment due to space and safety considerations. Therefore, this scenario shows the costs involved in expanding the use of the 2D EEMT into a classroom, a training environment for which operational equipment is not particularly appropriate.

Scenario 4: Changes in Skill Level Training

The 2D EEMT could be considered for training at skill levels other than "A" School, including basic electronics or advanced "C" School training, since the hardware and software configurations can support a variety of training applications and environments. Use of the 2D EEMT for more or less skilled training areas would necessitate acquisition of additional units appropriate to the extent of training planned and estimated student flow. Extensive facilities alterations would not be required to accommodate the 2D EEMT units. Hardware and software modifications would not be required. Development of lessonware at an appropriate skill level would be required and a new videodisc image base would be needed for the equipment in question. The number of videodisc copies required would depend on the number of 2D EEMT units installed. Training of instructors to operate 2D EEMT at other training levels would be necessary and student costs would vary according to student flow and to the length of the training program. The acquisition and life cycle costs associated with the application of 2D EEMT units in either of these environments would be comparable to those shown in Tables 9 and 13, respectively, with adjustments for the actual number of units to be acquired.

The costs of implementing this scenario would be relatively high since complete lessonware and videodisc development costs would be incurred along with acquisition equipment costs. The justification for implementing 2D EEMT units in these environments is the expansion of the training concept to new training areas and the ease of modification for future operational equipment modifications. Because of the many variables described and the uncertainty of

the alternative training equipment options available, no cost implications table has been developed for this scenario.

Scenario 5: Change in Physical Training Environment

This scenario is similar to Scenario 4 except that a physical change of environment rather than skill level change is considered. In Scenario 5, the 2D EEMT is implemented in a nonclassroom environment, such as shipboard or at a dock-side facility. The introduction of the 2D EEMT into these environments presents a particular challenge. The cost of changes to the hardware or the system configuration required to meet nonclassroom or nonlaboratory environments cannot be estimated from the present cost analysis. Facilities modifications, maintenance and operating costs would also vary from costs previously presented. Full lessonware development, including videodisc production, would be required unless the AN/SPS-10 operational equipment was the target of the training effort. Personnel and student costs would vary with student flow and the length of training. This scenario is included only to suggest that the instructional approach used by the 2D EEMT, with appropriate hardware modifications, might be adaptable to a range of diverse training environments. This possibility is supported by the results of Table 13 which indicate that expanded use of the 2D EEMT, as opposed to purchase of additional operational units, is more cost effective when training effectiveness is at least equivalent.

Summary

The analysis of the investment, operating, and maintenance costs of the 2D EEMT indicates that:

- When single units are purchased, acquisition of a 2D EEMT will result in a slightly higher cost for a first copy and a slightly lower cost for an additional copy than the acquisition of an AN/SPS-10 operational unit. Nearly all of the cost difference can be attributed to the lessonware development investment cost for the first copy of the 2D EEMT. Because a similar estimate of lessonware costs for the AN/SPS-10 was not available, the apparent cost difference is somewhat inflated.

- When multiple units are purchased, the 2D EEMT results in a life cycle cost savings over the AN/SPS-10 when three copies are acquired. However, to realize a life cycle cost savings of 50 percent, it would be necessary to purchase over 100 2D EEMT units instead of an equal number of AN/SPS-10 units.

- Considering only initial investment costs, the purchase of 20 2D EEMT units results in a cost savings of approximately 50 percent over the purchase of 20 AN/SPS-10 units. Since it was not possible to estimate the

cost lessonware acquisition for the AN/SPS-10 units, the estimate of 20 units to attain a 50 percent cost savings is conservative.

- The actual life cycle cost savings realized by using 2D EEMT units instead of operational equipment depends in large part on the initial investment cost of the operational equipment. In training environments where a single operational equipment trainer will be acquired, the initial investment costs must exceed about $143,000 or require support or operating expenditures well in excess of those for the AN/SPS-10 if the 2D EEMT is to show a lower life cycle cost estimate. Alternately, if less expensive operational equipment is necessary to support training, the 2D EEMT would show a lower life cycle cost estimate only if multiple units were required or the operational equipment had associated support or operating costs substantially higher than those for the AN/SPS-10.

- Considering the training costs per student-hour, a substantial savings can be realized by use of 2D EEMT units rather than operational equipment.

- The cost of modifying training equipment to accommodate technological changes in operational systems can be reduced by more than 50 percent if 2D EEMT units are already in use in the training environment.

VI. GENERAL CONCLUSIONS AND RECOMMENDATIONS

The findings of the TCT suggest some general conclusions regarding the training effectiveness, operational suitability, and costs of the 2D EEMT. This section summarizes these conclusions and presents recommendations related to each of these three areas of study.

Training Effectiveness

Conclusions

- When used in conjunction with actual equipment trainers, the 2D EEMT can reduce reliance on operational equipment trainers without a reduction in student troubleshooting performance.

- The use of the 2D EEMT is equally effective for low, middle, and high ability students.

- The 2D EEMT is an effective alternative to the use of operational equipment for providing extra study and remediation opportunities.

- When introduced into a training laboratory setting, the 2D EEMT provides an increased opportunity for troubleshooting practice on an individual basis, since safety and instructor monitoring requirements are substantially reduced.

- The skills and knowledge learned on the EEMT system generalize to the larger population of equipment maintained by ETs.

Recommendations

- The 2D EEMT should be used to supplement operational equipment in training environments which serve large student populations. Using the trainers to reduce reliance on operational equipment by as much as 50 percent would increase the student-equipment contact time and allow a higher student-instructor ratio, while maintaining a safe training environment.

- The use of the 2D EEMT for extra study/remediation training should be encouraged. With the development of appropriate lessonware, trainers allocated for this purpose could support a variety of courses with relatively little instructor supervision.

- Alternative techniques for integrating the 2D EEMT into existing training environments could result in observable increments in student performance and should be examined. EEMT lessonware should support hands-on training by providing the necessary background information and the opportunity to explore alternative solution strategies in a safe environment rather than duplicate hands-on experience acquired on operational equipment.

- Potential applications for the 2D-3D EEMT system should be identified and investigated. It is conceivable that training effectiveness might be substantially improved by using the integrated EEMT system since it would fill the gap between classroom and hands-on operational equipment training. BE&E training would serve as an excellent test environment since relatively naive students would have an opportunity to acquire generic hands-on experience in a safe environment.

Suitability

Conclusions

- While the 2D EEMT is generally reliable, 40 percent of the 118 required maintenance actions were related to touch panel malfunctions.

- The 2D EEMT was available for training about 72 percent of the time, when training is defined as laboratory and extra study/remediation.

- The spares package for the 2D EEMT available during the TCT was not adequate to maintain a 90 percent laboratory training availability.

- The maintainability of the 2D EEMT system was substantially affected by touch panel malfunctions. These panels were difficult to obtain and were replaced with a newer version which often resulted in delays of 3 to 6 months.

- The 2D EEMT could not be adequately maintained and logistically supported by Navy personnel at the ET "A" School, given the limited availability of spare parts during the TCT. Failures in major system components (e.g., microprocessor, videodisc player) are best resolved by the manufacturers.

- The 2D EEMT can be operated more safely by untrained students than operational equipment.

- The 2D EEMT is easily transported, assembled, and disassembled. It is significantly more mobile than operational equipment.

- The 2D EEMT is physically, functionally, and electrically compatible with the ET School environment.

- The tutorial lessonware has not been used. It was considered too lengthy and inflexible in presentation. The potential utility of the 2D EEMT in a classroom setting has not been demonstrated.

- The 2D EEMT lessonware currently in use does not adequately train safety procedures. This modification would not be difficult to make, however.

- Given the generic nature of the 2D EEMT, it is readily adaptable to some training environments with only changes in lessonware or the picture data base. The approach to training employed by the 2D EEMT may be appropriate for an even wider range of training environments, although hardware modifications would also be required.

- The data management features of the 2D EEMT were not fully examined. Those which existed during the TCT were extremely limited. Improvements in the software are needed to increase the utility of student performance records.

- Instructors were generally supportive of including the 2D EEMT in the ET "A" School environment, although it was not viewed as a replacement for operational equipment trainers.

- Students were noncommittal with respect to the 2D EEMT. While they reported that the trainer provided a greater opportunity to work on troubleshooting problems, working on the operational equipment was preferred.

Recommendations

- System malfunctions resulting from faulty touch panels and inadequate ventilation for equipment components in the student console should be remedied to increase the reliability of the 2D EEMT.

- A comprehensive spare parts package should be made available on-site to increase the maintainability of the 2D EEMT system. The package should be developed in view of the maintenance records to date.

- The 2D EEMT lessonware should be modified to monitor safe operating procedures and provide timely feedback in the form of printed warnings, graphic displays, or audible alarms in response to student safety violations.

- The 2D EEMT software should be modified in cooperation with school personnel to provide student performance data that is more timely, comprehensive, and easy to understand. This information should assist instructors so that laboratory and extra study/remediation can be tailored to meet individual and class training needs.

- The possibility of using the 2D EEMT in other training environments at the "A" School level should be examined. In a classroom setting, lessonware should emphasize equipment demonstration, manipulation and familiarization, rather than troubleshooting.

Cost

- When single units are purchased, acquisition of a 2D EEMT will result in a slightly higher cost for a first copy and a slightly lower cost for an additional copy than the acquisition of an AN/SPS-10 operational unit. Nearly all the cost difference can be attributed to the lessonware development investment cost for the first copy of the 2D EEMT. Because a similar estimate of lessonware costs for the AN/SPS-10 was not available, the apparent cost difference is somewhat inflated.

- When multiple units are purchased, the 2D EEMT results in a life cycle cost savings over the AN/SPS-10 when three copies are acquired. However, to realize a life cycle cost savings of 50 percent, it would be necessary to purchase over 100 2D EEMT units instead of an equal number of AN/SPS-10 units.

- Considering only initial investment costs, the purchase of 20 2D EEMT units would result in at least a 50 percent cost savings over the purchase of 20 AN/SPS-10 units.

- The actual life cycle cost savings realized by using 2D EEMT units instead of operational equipment depends in large part on the initial investment cost of the operational equipment.

- Considering the training costs per student-hour, a substantial savings can be realized by use of 2D EEMT units rather than operational equipment.

- The cost of modifying training equipment to accommodate technological changes in operational systems can be reduced by more than 50 percent if 2D EEMT units are already in use in the training environment.

Recommendations

- Because cost savings are associated with multiple 2D EEMT acquisitions, these trainers are recommended for school environments with relatively high enrollment and diverse training applications.

- The potential for use of the 2D EEMT system in conjunction with equipment that is more costly and sophisticated than the AN/SPS-10 radar should be examined since additional cost savings might be realized.

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APPENDIX A:
DATA COLLECTION FORMS

FOLLOW-UP RATING FORM

This form is to be used to rate the C School performance of the technician named in the box on the right. The information contained on this form will in no way be used to affect the technician's personal or work records, or enhance or impede his/her career status. This information is being collected to monitor the C School performance of those technicians whose training was monitored during their ET A School training at Great Lakes.

Technician Name: ______________________

C School Assignment: ______________________

Identifying Code: ______________________

Name and position of person completing this form: ______________________

About how long (in months) has the technician been at this school? __________

Compared to the other technicians in your classes, please indicate how you would rate this technician in each of the following areas:

	One of the Worst	Below Average	Average	Above Average	One of the Best
1. attention to safety?	1	2	3	4	5
2. ability to troubleshoot?	1	2	3	4	5
3. use of equipment manuals?	1	2	3	4	5
4. ability to work alone?	1	2	3	4	5
5. performance on written tests?	1	2	3	4	5
6. performance on hands-on tests?	1	2	3	4	5
7. overall C School performance?	1	2	3	4	5

About how many hours of remediation or extra study have been assigned to this technician so far? __________ Is that less than usual, about average, or more than usual? __________.

Do you have any additional comments about the performance of this technician in C School?

____

____

____

____

STUDENT CRITIQUE

Name: ____________________

Class: ____________________

It is requested that you take a few minutes of your time to help make Radar training more effective. This information is for evaluation purposes only and will be kept strictly confidential.

Circle the number that best expresses how much you agree with each statement below: 1 = Not At All and 5 = Very Much.

* * * * * * * * * * * * * * *

I. From your experience with the operational <u>AN/SPS-10 radar equipment</u>, to what extent would you agree with the following statements:

	Not At All				Very Much	Don't Know
a. There was enough training time on the equipment	1	2	3	4	5	?
b. Training time on the equipment was often wasted	1	2	3	4	5	?
c. A variety of training problems were provided	1	2	3	4	5	?
d. Equipment breakdowns interfered with training	1	2	3	4	5	?
e. Training time was mostly spent on troubleshooting	1	2	3	4	5	?
f. More time should be spent on trouble-shooting	1	2	3	4	5	?
g. I have a good understanding of how to maintain this equipment	1	2	3	4	5	?
h. I feel comfortable working on this equipment	1	2	3	4	5	?

i. Any additional comments about your training that involved the AN/SPS-10 equipment?

____

____

____

II. From your experience with the 2D EEMT subsystem (equipment pictures), to what extent would you agree with the following statements (if you have had no experience please skip this section):

	Not At All				Very Much	Don't Know
a. The lessons were useful for laboratory instruction	1	2	3	4	5	?
b. The lessons were useful for remedial instruction	1	2	3	4	5	?
c. The lessons were too simple	1	2	3	4	5	?
d. The lessons were too long	1	2	3	4	5	?
e. A variety of lessons were provided	1	2	3	4	5	?
f. The equipment was easy to use	1	2	3	4	5	?
g. The equipment was comfortable to use	1	2	3	4	5	?
h. Training time was mostly spent on troubleshooting	1	2	3	4	5	?
i. Training time on the equipment was often wasted	1	2	3	4	5	?
j. Equipment breakdowns interfered with training	1	2	3	4	5	?
k. The 2D trainer helped me to understand the AN/SPS-10 better	1	2	3	4	5	?

l. What did you like most about the 2D trainer? ____________________

____

____

m. What did you like least about the 2D trainer? ____________________

____

____

n. Any other comments about your training on the 2D EEMT subsystem?

____

____

Section A-3

Training Availability

	Device Number	Training Sessions* for week of ____									Comments
		D2	E2	M2	D3	E3	M3	D4	E4	M4	
EEMT Systems	A										
	B										
	C										
	D										
	E										
	F										
	G										
	H										
Operational Radar Equipment	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										

*D = day shift; E = evening shift; M = midnight shift

Please place a checkmark (√) in the appropriate box to indicate that equipment is available for training.

Section A-4

INSTRUCTOR CRITIQUE

I. About how long (in months) have you been an instructor at Great Lakes Naval Training Station? ______________

About how long (in months) have you been an instructor in the following areas? Please mark your current teaching assignment with an asterisk (*).

	Remediation	Classroom	Laboratory
Communications Systems:	________	________	________
Radar Systems:			
Power (4.1)	________	________	________
Transmitters (4.2)	________	________	________
Receivers (4.3)	________	________	________

* * * * * * * * * * * * * * * * *

Please **circle the number** which best expresses how much you would agree with each of the following statements: 1 = disagree strongly and 5 = agree strongly.

* * * * * * * * * * * * * * * *

II. From your general knowledge of and experience with simulators, do you think that including *simulators in training:*

	disagree strongly			agree strongly		don't know
a. is a good idea	1	2	3	4	5	?
b. can be more effective than actual equipment	1	2	3	4	5	?
c. can provide equivalent training with actual equipment	1	2	3	4	5	?
d. must look like actual equipment	1	2	3	4	5	?
e. can provide adequate training at a cost savings	1	2	3	4	5	?
f. allows for more complex training problems	1	2	3	4	5	?
g. is more reliable than actual equipment	1	2	3	4	5	?
h. teaches safety training better than actual equipment	1	2	3	4	5	?
i. provides more variety of training than actual equipment	1	2	3	4	5	?

	disagree strongly			agree strongly		don't know
j. is something you would use as an integral part of your teaching program	1	2	3	4	5	?

III. **Circle the number** which best shows how important you think each of the following factors is in evaluating the utility of simulators for providing training. 1 = unimportant - 5 = very important

	unimportant			very important		don't know
a. capability of the lessonware to meet a broad range of Navy training objectives	1	2	3	4	5	?
b. ability to simulate complexity of actual problems encountered in the field	1	2	3	4	5	?
c. a lower cost of hardware and operating expenditures compared to actual equipment	1	2	3	4	5	?
d. a high degree of similarity of the simulated equipment to the actual equipment	1	2	3	4	5	?
e. a savings in the amount of time required for training	1	2	3	4	5	?
f. the degree of control of Navy personnel over the design of the equipment	1	2	3	4	5	?
g. the capability of Navy personnel to modify existing or create new lessons for the training simulator	1	2	3	4	5	?
h. mobility of the equipment, for versatility of use in the classroom	1	2	3	4	5	?
i. reliability of performance of the equipment	1	2	3	4	5	?
j. ease of maintenance of the equipment	1	2	3	4	5	?
k. ability to more closely monitor student performance on the equipment	1	2	3	4	5	?

	unimportant			very important		don't know
l. a greater variety of material covered in lessons compared to actual equipment	1	2	3	4	5	?
m. ease of use for the training staff	1	2	3	4	5	?

* * * * * * * * * * * * * * * *

IV. Please indicate the amount of experience you have had with the 2D EEMT subsystem (**check all appropriate statements**).

a. ________ have heard about it, but never actually used it
b. ________ have seen a demonstration of it
c. ________ have had training on how to use it in the classroom
d. ________ have had limited use of it, as a reference for teaching
e. ________ have used it as a regular part of my teaching
f. ________ have been involved with writing lessons for use on it
g. ________ have been involved with the design and development of the unit
h. ________ have not heard about it, seen it, or used it (if checked, please skip the next section)

From your experience with the <u>2D EEMT subsystem</u>, to what extent would you agree with the following statements about the <u>free-play troubleshooting lessons</u>:

	disagree strongly			agree strongly		don't know
a. the lessons are well designed for laboratory instruction	1	2	3	4	5	?
b. the lessons are well designed for remediation instruction	1	2	3	4	5	?
c. the lessons meet course objectives	1	2	3	4	5	?

To what extent would you agree with the following statements about the <u>tutorial lessons</u>:

	disagree strongly			agree strongly		don't know
d. the lessons are well designed for laboratory instruction	1	2	3	4	5	?
e. the lessons are well designed for remediation instruction	1	2	3	4	5	?
f. the lessons meet course objectives	1	2	3	4	5	?

Overall, from your experience with the 2D EEMT subsystem, to what extent would you agree with the following statements:

	disagree strongly				agree strongly	don't know
g. it provides a useful supplement to operational equipment training	1	2	3	4	5	?
h. the authoring software is easy to use	1	2	3	4	5	?
i. the authoring software provides an effective method of developing new lessons	1	2	3	4	5	?
j. the record keeping features of the 2D simplify the task of individual student management	1	2	3	4	5	?
k. on a class basis, EEMT system management does not add significantly to the workload	1	2	3	4	5	?
l. student data produced by the EEMT system are helpful in student management	1	2	3	4	5	?
m. student data produced by the EEMT system are useful in assessing student abilities	1	2	3	4	5	?

* * * * * * * * * * * * * * * * *

V. Please indicate the amount of experience you have had with the 3D EEMT subsystem (**check all appropriate statements**).

a. ________ have heard about it, but never actually used it
b. ________ have seen a demonstration of it
c. ________ have had training on how to use it in the classroom
d. ________ have had limited use of it, as a reference for teaching
e. ________ have used it as a regular part of my teaching
f. ________ have been involved with writing lessons for use on it
g. ________ have been involved with the design and development of the unit
h. ________ have not heard about it, seen it, or used it (if checked, please skip the next section)

From your experience with the <u>3D EEMT subsystem</u>, to what extent would you agree with the following statements:

	disagree strongly				agree strongly	don't know
a. the hardware is too simple for it to be an effective training instrument	1	2	3	4	5	?
b. the lessons are well designed for instruction purposes	1	2	3	4	5	?
c. the lessons meet course objectives	1	2	3	4	5	?
d. the simulator is a better training instrument than the operational equipment	1	2	3	4	5	?
e. if given the opportunity, I will use the EEMT as an integral part of my teaching program	1	2	3	4	5	?

What changes do you think are needed to make the 3D EEMT a better training device?

____

____

____

* * * * * * * * * * * * * * * * *

VI. Any additional comments regarding the design and use of the EEMT system?

____

____

____

____

____

Section A-5

STRUCTURED INTERVIEW QUESTIONS

1. In your estimation, how is the 2-D EEMT system compatible with the ET School laboratory environment? How is it incompatible?

   a. Does the EEMT system make appropriate use of existing technical aids, guides, and manuals (FOMMS)?

   b. Does the system require special operational services, such as greater than normal electrical power, air conditioning, lighting, or space?

   c. How is the EEMT system compatible with remedial or voluntary study laboratory environments? How is it incompatible?

   d. How is the EEMT system configuration compatible and/or incompatible with team vs. individual training?

2. How is training for new operations or maintenance personnel currently conducted?

   a. How much time is currently allocated for training new operations or maintenance personnel (formal training vs. OJT)?

   b. Can training for EEMT operations personnel be adequately delivered in 2 weeks of formal training plus OJT?

      Can training for EEMT maintenance personnel be adequately delivered in 4 weeks of formal training plus OJT?

   c. Is current operations or maintenance personnel training for EEMT adequate? What could be added to it to improve the training?

   d. If you were in attendance at the EEMT Maintenance Training Course (October 25-30, 1981), do you, based on your present experience with the EEMT system, believe that it was a valuable course which provided adequate training?

      What improvements would you suggest for other courses of this type?

3. In what ways does the EEMT system incorporate basic safety principles appropriate to safe operation of the equipment?

   In what ways does the EEMT system incorporate unsafe operating conditions?

a. In what ways does the EEMT system train to basic safety principles?

In what ways does the EEMT system train to unsafe operating principles?

b. How does the EEMT system incorporation of basic safety or unsafe operating conditions compare to the operational equipment?

How does the EEMT system training of basic safety or unsafe operating conditions compare to the operational equipment?

4. How well is the EEMT system capable of training to appropriate levels of electronic maintenance skills?

a. How well does the EEMT system train to appropriate vacuum tube, solid state and/or LSI technology?

b. How effective is the presentation of material to the students using equipment images?

Are these images an advantage or disadvantage to the training of the electronics material?

c. How effective is the presentation of EEMT system material to the concepts of:

drill and practice?

cognitive or logical process?

team vs. individual training?

tutorial vs. free play lessons?

d. In what ways are free play lessons more appropriate than tutorials to the objectives of Area I training?

In what ways are free play lessons less appropriate to the objectives of Area I Radar than tutorials?

e. How easily can the EEMT system adapt to changing technologies, objectives, or job demands?

f. How easily can EEMT operations personnel modify the EEMT system to adapt to changing technologies, objectives, or job demands?

5. How easy is it to understand the EEMT system technical documentation (operations, maintenance, systems programming)?

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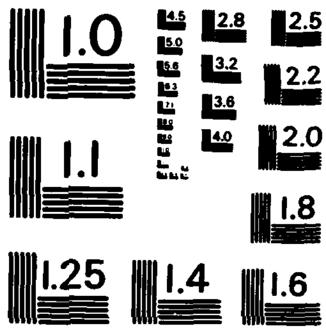

a. How easy is it to use the EEMT system technical documentation?

b. How complete and comprehensive is the EEMT technical documentation?

c. How available to EEMT system operators or maintainers is the EEMT technical documentation?

d. What process is involved in revising or modifying the EEMT technical documentation?

e. How frequently is it necessary to revise or modify the EEMT documentation, or how frequently should it be done?

APPENDIX B:
DATA ANALYSIS TABLES

Table B-1

Primary Power Performance Test Scores as a Function of Student Ability Levels and Training Equipment Availability for Historical Data Samples

Student Ability*		Operational Equip. Only	EEMT Extra Study Only	EEMT Lab Plus Extra Study	Overall
		Training Equipment Availability			
Low	N	24	24	24	72
	$\bar{X}$	73.92	82.17	83.54	79.88
	σ	20.72	19.31	13.08	18.27
Middle	N	24	24	24	72
	$\bar{X}$	80.42	88.73	89.23	86.12
	σ	21.11	18.80	10.18	17.57
High	N	24	24	24	72
	$\bar{X}$	85.34	92.75	97.16	91.75
	σ	15.82	10.65	5.89	12.37
Overall	N	72	72	72	216
	$\bar{X}$	78.89	87.88	89.98	85.92
	σ	19.66	17.07	11.48	16.92

*Defined by ET School cumulative grade average prior to AN/SPS-10 Primary Power.

Table B-2

Number of Troubleshooting Problems
Worked as a Function of Training Conditons

Training Mode	Training Format		EEMT Laboratory Training*	EEMT Extra Study/ Remediation	EEMT Total**	Operational Equipment
High EEMT Supplement	Individual	N	27	27	27	27
		$\bar{X}$	3.59	1.04	4.63	3.78
		σ	2.10	1.43	2.57	1.12
	Pair	N	23	22	24	24
		$\bar{X}$	4.26	1.36	5.50	4.63
		σ	2.67	1.84	2.93	1.79
	Overall	N	50	49	51	51
		$\bar{X}$	3.90	1.18	5.04	4.18
		σ	2.38	1.62	2.76	1.52
Low EEMT Supplement	Individual	N	28	28	28	28
		$\bar{X}$	1.57	1.00	2.61	6.29
		σ	1.32	2.16	2.63	1.72
	Pair	N	27	27	27	27
		$\bar{X}$	2.41	1.30	3.70	6.78
		σ	1.55	2.07	2.84	1.67
	Overall	N	55	55	55	55
		$\bar{X}$	1.98	1.15	3.15	6.53
		σ	1.48	2.10	2.77	1.70
Operational Equipment Only	Individual	N	-	-	-	24
		$\bar{X}$	-	-	-	7.46
		σ	-	-	-	2.25
	Pair	N	-	-	-	27
		$\bar{X}$	-	-	-	7.63
		σ	-	-	-	2.10
	Overall	N	-	-	-	51
		$\bar{X}$	-	-	-	7.55
			-	-	-	2.15

*Training also included the "normal operation" and "light off" lessons for all students.

**While the EEMT total is the sum of laboratory and extra study/remediation, slight variations can result from missing data.

Table B-3

Primary Power Performance Test Scores as a Function of Student Ability Levels and Training Mode for Study 2

Training Mode		Student Ability Level* Low	Middle	High	Overall
High EEMT Supplement	$\underline{N}$	14	14	19	47
	$\bar{X}$	81.24	75.40	88.88	82.59
	σ	10.35	19.23	11.27	14.74
Low EEMT Supplement	$\underline{N}$	16	19	18	53
	$\bar{X}$	71.53	72.69	91.21	78.63
	σ	23.64	27.15	11.97	23.38
Operational Equipment Only	$\underline{N}$	19	15	13	47
	$\bar{X}$	72.05	84.10	87.28	80.11
	σ	26.02	19.48	12.58	21.64
Overall	$\underline{N}$	49	48	50	147
	$\bar{X}$	74.51	77.05	89.30	80.37
	σ	21.82	22.85	11.73	20.33

*Defined by ET School cumulative grade average prior to AN/SPS-10 Primary Power training.

Table B-4

"C" School Follow-Up Questionnaire Results

Question*		Training Mode		
		High EEMT Supplement	Low EEMT Supplement	Operational Equipment Only
1. Attention to Safety	N	26	35	37
	$\bar{X}$	3.62	3.40	3.24
	σ	0.90	0.77	0.49
2. Ability to Troubleshoot	N	26	33	30
	$\bar{X}$	3.23	3.36	3.47
		0.99	0.90	0.90
3. Use of Equipment Manuals	N	26	35	37
	$\bar{X}$	3.31	3.26	3.43
	σ	1.01	0.85	0.77
4. Ability to Work Alone	N	26	35	37
	$\bar{X}$	3.23	3.37	3.32
	σ	0.95	0.81	0.71
5. Performance on Written Tests	N	22	31	34
	$\bar{X}$	3.27	3.35	3.26
	σ	0.83	1.02	0.83
6. Performance on Hands-On Tests	N	26	35	37
	$\bar{X}$	3.23	3.54	3.32
	σ	1.03	0.92	0.85
7. Overall "C" School Performance	N	26	35	37
	$\bar{X}$	3.23	3.37	3.38
	σ	1.03	0.77	0.76

*Supervisors rated technicians on a five-point scale for each item where 1 = one of the worst, 2 = below average, 3 = average, 4 = above average, and 5 = one of the best.

Table B-5

Instructor Critique Results

Selected Questions	Mean Rating of Agreement*	Number of Respondents	Standard Error
From your general knowledge of and experience with simulators, do you think that including simulators in training:			
o is a good idea	3.66	47	.18
o can be more effective than actual equipment	1.72	47	.15
o can provide equivalent training with actual equipment	2.20	46	.17
o must look like actual equipment	2.83	42	.23
o can provide adequate training at a cost savings	2.32	37	.17
o allows for more complex training problems	2.59	46	.21
o is more reliable than actual equipment	1.87	46	.14
o teaches safety training better than actual equipment	1.30	47	.08
o provides more variety of training than actual equipment	2.43	47	.20
o is something you would use as an integral part of your teaching program	2.94	46	.18

*scale: 1 = disagree strongly, 5 = agree strongly

Table B-5 (cont.)

Selected Questions	Mean Rating of Importance*	Number of Respondents	Standard Error
How important do you think each of the following factors is in evaluating the utility of simulators for providing training:			
• capability of the lessonware to meet a broad range of Navy training objectives	4.26	46	.14
• ability to simulate complexity of actual problems encountered in the field	4.30	46	.15
• a lower cost of hardware and operating expenditures compared to actual equipment	3.78	45	.18
• a high degree of similarity of the simulated equipment to the actual equipment	3.87	46	.20
• a savings in the amount of time required for training	3.40	45	.19
• the degree of control of Navy personnel over the design of the equipment	3.56	45	.16
• the capability of Navy personnel to modify existing or create new lessons for the training simulator	4.49	47	.11
• mobility of the equipment, for versatility of use in the classroom	3.15	40	.21
• reliability of performance of the equipment	4.68	47	.11
• ease of maintenance of the equipment	4.63	46	.08
• ability to more closely monitor student performance on the equipment	4.17	47	.14
• a greater variety of material covered in lessons compared to actual equipment	3.84	45	.17
• ease of use for the training staff	4.22	46	.15

*scale: 1 = unimportant, 5 = very important

Table B-5 (cont.)

Selected Questions	Mean Rating of Agreement*	Number of Respondents	Standard Error
From your experience with the 2D EEMT subsystem, to what extent would you agree with the following statements about the free-play troubleshooting lessons:			
• the lessons are well designed for laboratory instruction	2.74	46	.15
• the lessons are well designed for remediation instruction	3.26	46	.16
• the lessons meet course objectives	3.11	45	.16
Overall, from your experience with the 2D EEMT subsystem, to what extent would you agree with the following statements:			
• it provides a useful supplement to operational equipment training	3.32	47	.20
• the authoring software is easy to use	3.06	35	.22
• the authoring software provides an effective method of developing new lessons	2.39	26	.26
• the record keeping features of the 2D simplify the task of individual student management	2.78	45	.20
• on a class basis, EEMT system management does not add significantly to the workload	2.42	45	.17
• student data produced by the EEMT system are helpful in student management	2.42	45	.15
• student data produced by the EEMT system are useful in assessing student abilities	2.36	45	.17

*scale: 1 = disagree strongly, 5 = agree strongly

Table B-6

Student Critique Results

Selected Questions	Mean Rating of Agreement*	Number of Respondents	Standard Error
From your experience with the operational AN/SPS-10 radar equipment, to what extent would you agree with the following statements:			
• There was enough training time on the equipment	3.15	108	.10
• Training time on the equipment was often wasted	1.65	108	.10
• A variety of training problems were provided	3.97	106	.10
• Equipment breakdowns interfered with training	1.54	108	.09
• Training time was mostly spent on troubleshooting	3.75	109	.10
• More time should be spent on troubleshooting	3.83	105	.12
• I have a good understanding of how to maintain this equipment	3.77	107	.09
• I feel comfortable working on this equipment	4.09	108	.09

*scale: 1=not at all, 5=very much

Table B-6 (cont.)

Selected Questions	Mean Rating of Agreement*	Number of Respondents	Standard Error
From your experience with the 2D EEMT subsystem (equipment pictures), to what extent would you agree with the following statements:			
• The lessons were useful for laboratory instruction	2.91	97	.10
• The lessons were useful for remedial instruction	3.14	51	.13
• The lessons were too simple	2.99	95	.10
• The lessons were too long	2.43	94	.12
• A variety of lessons were provided	3.49	89	.12
• The equipment was easy to use	3.50	97	.13
• The equipment was comfortable to use	3.36	97	.13
• Training time was mostly spent on troubleshooting	3.53	96	.11
• Training time on the equipment was often wasted	2.47	97	.13
• Equipment breakdowns interfered with training	2.49	96	.15
• The 2D trainer helped me to understand the AN/SPS-10 better	2.90	96	.12

*scale: 1=not at all, 5=very much

Table B-7

Frequent Comments from Student Critiques
Concerning 2D EEMT Training

Comment	Number of Respondents Like	Dislike
Reliability:		
• general malfunctions and system bugs	0	9
• touch panel drift	0	19
• system lock-up problem	0	4
Fidelity:		
• realistic representation/ not realistic enough	3	4
• tells student if a relay is energized, closes interlocks, hooks up meters, etc.	2	6
• set-up and use of test equipment	3	4
Lessonware:		
• simple/too simple; you can easter-egg problems	1	4
• variety of problems; component rather than wire problems	2	5
• color/poor picture quality; cannot read reference designations	3	12
• contributes to bad safety habits (or fails to support good ones)	0	6
System/Lesson Operation:		
• easy to use; convenient	6	0
• comfortable	10	0
• faster than operational equipment; able to solve more problems	13	0
• too slow	0	4
• hard to access components; lots of moves required	0	18
• reduced safety risk	6	0

Table B-7 (cont.)

Comment	Number of Respondents Like	Dislike
General:		
• positive/negative	2	4
• good troubleshooting practice	8	0
• availability in extra study	3	1
• need to hear blowers, etc.; too easy to forget settings	0	3
• gave good system overview; helped with system familiarity	6	0

APPENDIX C:
2D CONTRACT-RELATED DATA

2D Contract-Related Data

1. Basic Contract #N00123-80-R-0327 (2D only) - Duration: June, 1980-December, 1981

Purpose: This contract was for the purpose of providing 20 2D EEMT units

a. Total Contract Costs were:

Cost	$ 485,551
Fee	48,555
CAS	3,546
Total	$ 537,652

b. Contract Line Items Included:

20 EEMT	$ 402,229
2 inst terminals	2,143
Technical support services	9,233
Manufacturer's training course	6,092
Technical data	114,409
CAS 414 (CMF)	3,546
Total	$ 537,652

c. Proposed cost of additional units was:

Cost	$ 15,720
Fee	1,572
CMF	53
Total	$ 17,345

2. EEMT Lessonware Development: Contract Modifications PO1, PO2 -Duration: October, 1980-April, 1982

Purpose: These contract modifications were necessary for the development of training software and lessonware for 2D and 3D EEMT units.

a. This task included development of:

o AN/SPS-10 - tutorial free play lessonware

- AN/SLQ 32 (ESM) tutorial lessonware

- Data bases for the AN/SPS-10, AN/SLQ-32, AN/WSC-3, and generic training programs

b. Total contract costs for this task were:

Cost	$ 710,524
Fee	67,500
CAS	5,963
Total	$ 783,987

c. Contract line items were:

Program management	$ 36,751
Configuration management	44,940
Data Collection for lessonware	186,880
Lessonware authoring/data base generation	250,554
Modifications to software to drive 3D NPRDC hardware system	68,408
Technical publications	118,878
Support services	4,110
CAS	$ 5,963
Total	$ 710,504

3. Convert to Videodisc and Touch Panels: Modification P06 - Duration: July, 1981-December, 1981

Purpose: This contract modification was for the purpose of changing the 2D EEMT system from Bruning microfiche/sonic pens to videodisc and touch panels. Costs shown include the hardware (adjusted against cost of previous hardware); software; documentation changes

a. Total Contract Cost:

Cost	$ 53,322
CAS	532
Total	$ 53,854

4. Cost of Government Furnished Equipment - Duration: June, 1977-December, 1979, (approximately)

a. The University of Southern California received approximately $488,000 over 2½ years for training system software, basic GMTS design/configuration, and free play strategy software.

b. Contract costs for 6 GMTS units included:

$8-10,000 terac per each	$ 48-60K
$5,000 graph pen	30K
Total for basic equipment	$ 78-90K

5. Modify lessonware and GFE software: Modification P07 - Duration: September, 1981-May, 1983.

Purpose: This contract modification was required to modify government furnished software for training system and free play strategy. Because of the hardware changes, software modifications were necessary, including all data base structures and the reentry of all lessonware.

a. Total Contract Costs were:

Cost	$ 455,307
Fee	44,607
Total	$ 499,914

b. Line items included:

(L1) The update and revision of government furnished syllabus/curriculum documentation for representative systems lesson specifications. Revisions were made to:

9 SPS-10 lessons and 18 GFE SLQ-32 lessons

Changes required deletion of 5 original AN/SPS-10 lessons and the creation of 6 new lessons @ $53,255

(L2) The redesign of government furnished lessonware specification for generic systems. Twenty-six generic lessons (87½ hours) were modified for the redesigned 3D EEMT.

(This is a 3D task) 199,146

(L3) Modification of lesson specifications for test equipment 13,531

(L6) Expanded AN/SPS-10 free play lessonware from the original 15 fault problems to 30 problems. The 15 new lessons included 7 power supply fault isolations problems and 8 AC voltage regulator isolation problems. Costs for this lessonware development were $3,802.60 per lesson. 57,039

6. Purchase of 20 2D units: Modification P09 - Duration: November, 1981-May, 1982

Purpose: This contract modification was to allow the purchase of 20 additional 2D units

a. Total contract costs were:

Cost	$ 315,460	(20 @ 17,345/unit--basic contract price)
Fee	31,440	
Total	$ 346,900	

7. Data base restructuring: Modification P15 - Duration: April, 1983 - July, 1983.

Purpose: This contract modification was to allow the addition of a step control function in steps 16 and 17 of the new data base

a. Total Contract Costs were:

Cost	$ 69,601
Fees	6,776
Total	$ 76,377

8. Refund: Modification P16

Purpose: This contract modification was for the refund of $ 130,000 for software development not required due to other contract modifications

9. Refund: Modification 17

Purpose: This contract modification was for the refund of $50 in fees to the government.

10. Spare Parts Contract

Spare parts for the 2D EEMT units consist of components purchased and delivered by NPRDC and components delivered by Cubic Corporation. The total value assigned to this spares package, as determined from the proposed spares contract and conversations with the project monitor, is:

Cubic spares package	$ 66,279
NPRDC purchases	36,959
Total	$ 103,238
20 2D EEMT units	÷ 20
per unit	$ 5,162

APPENDIX D:
COST NOTES

Cost Notes for Tables 8, 9, 10, 11, 12, 13, 14

A The total cost of the station/console includes the following line items listed in contract modification P06:

Desk	$	626.56
Casters		22.36
Rear Panels		49.84
Enclosures		400.00
Drawer		26.80
Modification		25.00
	$	1,150.56

B The total cost of system interfaces/controllers includes the following line items listed in contract modification P06:

A/N Controller	$	280.00
Graphic Controller		375.00
Electronic Chassis		50.00
W/W Board		233.47
ICS		76.80
Wire		45.00
Power Strips		28.40
Touch Panel Interface		125.00
Cabling		25.00
Ribbon Cables		75.00
	$	1,313.67

C These cost estimates are shown in the Basic Contract as a "miscellaneous" line item.

D Fabrication for the first copy was determined by using the cost for an additional unit based on contract price and subtracting the cost of freight and equipment costs (also based on contract figures) and adding the fee for one terminal. This resulted in the following calculation:

Additional Unit	
Basic Contract price	$ 17,345.00
Less freight	- 112.50
Cost per unit	$ 17,232.50
Printer	974.00
	$ 18,206.50
Less Equipment Cost	- 11,534.00
	$ 6,672.50
Fee for Terminal	105.00
Total fabrication cost	$ 6,777.50

Additional copy costs do not reflect the terminal fee.

E The prototype development costs were determined from Basic Contract costs. Relevant modifications (P06) were added and the costs of software/lessonware were subtracted. Seventy percent of technical data costs (as determined from Item 5, Basic Contract) and technical support costs were added. The additional unit cost times 20 units was subtracted. Finally, government furnished equipment costs were added. The resulting calculation was as follows:

Total Basic Contract	$ 404,884
Videodisc format modifications (P06)	53,854
	$ 458,738
Software/lessonware	- 89,449
	$ 369,289
70% Engineering Technical Data	80,615
	$ 449,904
Technical Support	9,233
	$ 459,137
20 Additional 2D EEMT Units	- 346,900
	$ 112,237
GFE (hardware)	83,000
	$ 195,237 Development costs

F Prototype user documentation reflected the remaining 30 percent of the technical data cost from contract documents (see Cost Note E). Five percent was considered adequate for first copy costs.

G The cost of shipping the 2D EEMT to its destination is not included in these cost estimates. Note that the total hardware cost of additional units ($17,232) plus a shipping charge ($113) equals the $17,345 paid by the government for each additional 2D EEMT unit.

H Software development costs were calculated using GFE software figures and adding contract modification amounts from EEMT software and documentation enhancement modification (P07) and data base structure modifications (P15). Task S5 of P07 was not included as it addressed the 3D EEMT software only. This results in the following calculation:

GFE software	$ 160,000
Strategy specification (P07, S1)	19,152
Operating system (P07, S3)	19,022
Software consolidation (P07, S4)	39,285
Data base structure modifications (P15)	76,377
	$ 313,836

I Next copy and additional copy costs were assumed to be $50 for diskettes.

3 Prototype copy structured lessonware development costs were derived from contract modification EEMT lessonware development (P02) less costs for 3D lessonware and documentation of generic lessonware. In addition, the cost of free play lessonware for Primary Power radar was subtracted out. The resulting amount was reduced by 80 percent to reflect Primary Power tutorial lessonware development only. GFE lessonware costs were added. Primary Power free play lessonware costs were then added. Videodisc production costs were determined from contract modifications (P06). Money refunded for 3D lessonware not developed was subtracted. Lessonware modifications from contract modification P07 were added. The resulting calculation was:

GFE Lessonware	$ 160,000
Free play Lessonware	114,078
20% Structured Lessonware	96,525
Videodisc Production	17,222
Miscellaneous	620
Lessonware/software modifications P07	30,420
	$ 418,865

First copy development costs reflect lesson development for 30 free play lessons, videodisc production, development and mastering.

Lesson development	$ 114,078	30 free play lessons at $3,803 per lesson (Source: Contract Modification P07, L6)
Videodisc development	$ 1,000	Photography
	750	SME support
	11,480	Videodisc support
	335	Camera, film, processing
	$ 13,565	(For three videodiscs) (Source: Contract Modification P06)
	$ 4,522	Per videodisc production
	4,700	Premastering (Source: Army Signal Corps Military Interdepartmental Purchase Request #N6822182 MP20098)
	$ 1,700	Master (Source: Project Monitor Communication)
	$ 10,922	Total videodisc production

Videodisc production cost differences between prototype and next copies reflect multiple disk production and demo disk production costs for the prototype not reflected in the next copy.

Lesson development and videodisc development for first copy:	$ 114,078
	10,922
	$ 125,000

K Lessonware acquisition costs for a 2D EEMT first copy and an additional copy reflect purchase of printer paper, floppy disks (20 @ $7), and a single copy of the videodisc. The assumption is made that the additional copy videodisc is obtained at the time that the next copy unit is obtained, avoiding the remastering costs of the videodisc.

Printer paper	$ 480
Floppy discs	140
Videodisc	17
	$ 637

L The spares package amount was determined from contract specifications and conversations with the NPRDC Contract Monitor for parts purchased and allocated to a per unit base (see Appendix C).

M Facilities costs are based on T. Eggemeier, Life Cycle Cost Estimation of Simulated vs. Actual Equipment Maintenance Training for the F-16 Avionics Intermediate Shop (AFHRL Advanced Systems Division, Wright-Patterson AFB, OH: March 1979). The replacement cost of space in that study was estimated to be $16.27 per square foot (sq. ft.). Adjusted for inflation from 1977 (original date of estimate) results in a 1981 replacement cost of space of $30 per square foot. Space allocated for the eight 2D EEMT units used in the Primary Power training laboratory was 200 sq. ft. For the 10 operational equipments, 400 sq. ft. were used. All costs are per unit costs.

N Acquisition management was included in development costs shown in Table 8.

O Investment costs for the 2D EEMT reflect the spares package shown in Table 8. The operating year sustaining investment costs for this trainer were assumed to be 5 percent of the cost of the equipment. Actual sustaining costs for the 2D EEMT were complicated by the establishment of commercial repair contracts. For the operational equipment, Navy maintenance documents available for the TCT were considered to underestimate the actual costs of repair over a life-cycle period. Actual parts costs for the period of January -December 1983 were determined to be $191, which did not account for major system components which could fail once per every 5 year cycle. Therefore, the 5 percent of equipment cost amount shown anticipates major component breakdown spread over the life-cycle. All costs are per unit costs.

P Maintenance costs were derived from personnel allocations to 2D EEMT maintenance with pay scales from the Navy Composite Standard Military Rate Table deflated to 1981 rates according to the Consumer Price Index (CPI). This maintenance level assumes one ET3 and two ET2 level personnel full-time. It also includes overhead as follows: one chief petty officer at 10 percent and one petty officer first class at 25 percent, based on staffing responsibility for 30 and 12 persons, respectively. This total was then allocated over the 40 2D EEMT units over which the maintenance staff had responsibility. All costs are per unit costs.

Q Operating cost estimates were determined from conversations with the base facilities administrator. Utilities costs were estimated to be $7 per square foot per year. The 2D EEMT laboratory housing 8 2D EEMT units was estimated to be 200 square feet. All costs are in per unit costs.

R Operating year FOMM and lessonware materials costs were determined from the annual printing costs charged to the AN/SPS-10 Radar training area. No reduction was made for distribution of costs over all of the AN/SPS-10 Radar areas, since the full set of manuals and workbooks would be required for any one section of AN/SPS-10 Radar training. Annual printing charges to AN/SPS-10 Radar areas is estimated at $63,250.

S Updating of laboratory exercises/materials was estimated at 1 week per year for an instructor (GS-9, Step 5 or ET 3). Operational equipment lessons are altered very infrequently. Existing problems cover all primary areas of the equipment and can be randomly assigned. In addition, laboratory instructors can insert equipment faults by hand as needed. For the 2D EEMT, the existing 30 free play lessons are considered a sufficient pool for the life-cycle of the equipment. TCT results (Table B-2) show fewer than five problems worked per student. Therefore, allocated time is for debugging and minor changes. The cost calculation was as follows:

$25,956	(GS-9, Step 5 annual salary, in 1981 dollars) (Source: Mark, L.J., Kribs, H.D., Schuler, J.W., and Brown, J.E. A life cycle cost model for an electronic maintenance trainer (NPRDC Special Report 82-33). p. A-13.
$ 10,543	(ET-3 annual salary in 1981 dollars) (Source: Navy Composite Rate Table, 1982)
$ 18,250	average of two salaries
÷ 52	
$ 350	per week

T Laboratory instructor costs were assumed to be an average for a GS-9, Step 5/ ET3 pay scale. One full-time instructor was assumed. See Cost Note R.

U Overhead for instructor personnel was determined to be at 55 percent. Source: Mark, L.J., Kribs, H.D., Schuler, J.W., and Brown, J.E. A life cycle cost model for an electronic maintenance trainer (NPRDC Special Report 82-33). p. A-13.

V The calculation for determining student wages for ET "A" School was as follows:

$23.85/day x 4 training days/week x 66 students/week x 50 weeks/year = $314,820

W Miscellaneous student support costs were estimated to be $110/week per student. This estimate was obtained from ET "A" School personnel. The calculation is:

$110/week/student x 66 students/week x 50 weeks/year = $363,000/year

X The cost of an operational equipment AN/SPS-10 was derived from estimates of purchase price in 1979 ($37,500) adjusted to 1981 dollars based on the producer price index of the US GPO Economic Indicators.

Y Maintenance costs were determined from RCA personnel allocations and salary schedules and apportioned for the Primary Power laboratory AN/SPS-10 units. All costs shown are per unit costs.

Z Operating costs were determined from conversations with the base facilities administrator. Utilities costs were estimated to be $7 per square foot per year. The operational equipment laboratory was determined to be 400 square feet in area. All costs shown are per unit costs.

AA 2D EEMT hardware costs include two next copies and eight additional copies, based on the assumption that the next copy instructor terminal (printer) can support four additional copies. All other equipment costs are life-cycle costs (Tables 9, 10, 11) for 10 units.

BB AN/SPS-67 equipment costs were derived from: Mark, L.J., Kribs, H.D., Schuler, J.W., and Brown, J.E. A life cycle cost model for an electronic maintenance trainer (NPRDC Special Report 82-33). p. A-5.

CC AN/SPS-67 and AN/SPS-10 curriculum development costs were derived from: Mark, L.J., Kribs, H.D., Schuler, J.W., and Brown, J.E. A life cycle cost model for an electronic maintenance trainer (NPRDC Special Report 82-33). p. A-13 for curriculum development costs. Curriculum maintenance costs for the AN/SPS-67 were assumed to be comparable to estimates for the AN/SPS-10.

DD 2D EEMT Lessonware

15 free play lessons (114,078 ÷ 2)	$ 57,039
FOMMS/technical documentation ($63,250 x 2 to represent redevelopment of all documentation)	126,500
	$ 183,539
AN/SPS-10 lessonware development (42,190 ÷ 2)	$ 21,095
FOMMs/technical documentation	126,500
	$ 147,595

EE One next copy and four additional copies are assumed. Rf. Table 8.

FF Structured 2D EEMT lessonware development costs were determined from the total software/lessonware development contract costs (P02), less 3D EEMT software modifications costs and documentation of generic lessonware costs. The resulting amount was reduced by free play lessonware costs and further reduced by 80 percent to reflect Primary Power structured lessonware costs. The calculation is:

Total P02 cost	$ 783,987
3D software modifications	- 68,408
Generic lessonware documentation	-118,878
Primary Power free play lessonware	-114,078
	$ 482,623
Reduced by 80% to show Primary Power structured lessonware only	-386,098
	$ 96,525

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